

SECTION 701 MAINTENANCE AND PROTECTION OF TRAFFIC:

701-1 Description:

The work under this section shall consist of providing flagging services and pilot trucks, and furnishing, installing, maintaining, moving and removing barricades, warning signs, lights, signals, cones, and other traffic control devices to provide safe and efficient passage through and/or around the work and to protect workers in or adjacent to the work zone. The work shall be done in accordance with the requirements of Part VI of the Manual on Uniform Traffic Control Devices (MUTCD) and the associated Arizona Department of Transportation supplement. When referred to herein, these documents will be referred to as MUTCD and associated ADOT Supplement.

The requirements of the MUTCD and associated ADOT Supplement shall be considered as the minimum standards for the protection of workers and the traveling public.

When a traffic control plan is included in the project plans, this plan shall govern unless an alternate plan, acceptable to the Engineer, is submitted by the contractor. If no traffic control plan is provided or if the contractor desires to deviate from the provisions for maintaining traffic as described in this section, it shall submit to the Engineer for approval a proposed sequence of operations and a compatible method of maintaining traffic. The proposal shall be submitted early enough to allow at least two weeks for review and approval before use of the proposed traffic control plan.

The traffic control and safety plan of the contractor, along with the contractor's work schedule and actual operations, shall be such that no condition that is considered to be unsafe, in the opinion of the Engineer, shall exist. The traffic control plan shall assure that miscellaneous operations occurring throughout the work, as well as during the final stages, are adequately protected. As a result of effective planning and efficient scheduling of the type and quantity of work, the duration, degree, length, amount, size, etc., of any traffic restriction or lane closures shall be limited to that absolutely necessary to provide a safe condition for both traffic and construction personnel.

701-2 Materials (Equipment, Workers, Devices and Facilities):

701-2.01 General:

Except as specified herein, all equipment, procedures used by workers, devices and facilities shall conform to the requirements of the MUTCD and associated ADOT Supplement.

701-2.02 Flashing Arrow Panels:

Flashing arrow panels shall conform to the requirements of Section 6F-3 of the MUTCD and associated ADOT Supplement with the following additions:

Each arrow panel shall have its own independent power source. The power source shall be capable of supplying adequate continuous power for the sign operation over

extended periods of time. Fuel capacity shall be such as to provide for at least 12 hours of continuous operation without refueling. Panels may be solar powered with adequate energy source to provide for at least 12 hours of continuous operation without refueling or recharging.

701-2.03 Temporary Concrete Barrier:

Temporary concrete barrier shall conform to the requirements of Subsections 910-2 and 910-3 of these specifications for precast sections.

701-2.04 Temporary Impact Attenuation Devices:

Temporary impact attenuation devices shall conform to the requirements of Subsections 702-2 and 702-3 of these specifications for the type of device shown on the project plans or as approved by the Engineer.

701-2.05 Temporary Pavement Markings:

(A) Temporary Raised Pavement Markers:

Temporary Pavement Markers may be Temporary Reflective Markers, Permanent Reflective Markers (used as Temporary) or Non-Reflective Markers, as required on the Project Plans or as approved by the Engineer.

Temporary Pavement Markers shall be in conformance with Standard Drawings 4-M-2.02, 4-M-2.05, and Subsections 706-2 and 706-3 of these specifications and shall be included on a list of pre-approved products maintained by the Department.

Chip Seal Pavement Markers shall conform to Standard Drawing 4-M-2.05. The Chip Seal marker body and cover shall be manufactured from a polyurethane material conforming to the following requirements:

	Requirement	ASTM Test Method
Specific Gravity (Min.)	1.19	D 792
Hardness (Min.)	80A	D 2240
Tensile Strength (Min. PSI)	4,600	D 412
Ultimate Elongation (Min. %)	330	
Modulus @ 300% PSI	1,000	
Stiffness @ -20 °F (Min. PSI) 70 °F (Min. PSI)	17,000 900	D 1053
Compression Set 22 hrs. @ 70 °C	65	D 395
Taber Abrasion; CS 17 wheel, Wt. Loss (mg/1000 cycles)	3	-----

Reflective tape shall be metalized polycarbonate microprism retroreflective material with acrylic backing or equal. The tape shall have a minimum reflectance equal to or greater than 1,800 candelas per foot-candle per square foot at 0.10-degree observation and zero-degree entrance angles.

(B) Pavement Marking Paint:

Paint for temporary striping, arrows, symbols and legends shall be white or yellow and shall conform to the requirements for permanent striping paint as set forth in Section 708 of these specifications and as indicated on the project plans or as approved by the Engineer. Paint for temporary symbols and legends shall be white and shall meet the same requirements as temporary striping.

(C) Preformed Pavement Markings:

Preformed Pavement Markings shall be either Type II (Temporary-Removable) or III (Temporary-Nonremovable), as indicated on the project plans or as approved by the Engineer. Preformed Pavement Markings shall be in conformance with the requirements of Section 705 of these specifications and shall be included on a list of pre-approved products maintained by the Department.

701-2.06 Temporary Sign Supports:

Temporary Sign Supports may be wood, steel or aluminum, at the option of the contractor and shall be approved by the Engineer prior to installation. Wood posts shall be Southern Pine, Douglas Fir or other soft wood. Wood posts need not be treated. Embedded posts shall meet the criteria established under NCHRP Report 350 for breakaway sign supports.

Angle braces will not be allowed.

701-2.07 Delineators:

Delineators shall be as shown on the plans and shall be in conformance with Standard Drawing 4-M-4.01 and Subsection 703-2 of these specifications.

701-2.08 Barricades:

Type I barricades having a minimum of 270 square inches of retroreflective area facing traffic, and otherwise conforming to Section 6F-5(f) of the MUTCD, may be used in lieu of Type II barricades in freeway or other high speed applications, unless specifically excepted in the project plans.

All sheeting for barricades shall be a minimum of Type II sheeting, conforming to AASHTO M 268.

701-3 Construction Requirements:

701-3.01 General:

The contractor shall provide for the adequate protection of all vehicular and pedestrian traffic and workers through any portion of the work where construction operations interfere with, obstruct, or create a hazard to the movement of traffic.

At the pre-construction conference, the contractor shall provide the Engineer with the name of the contractor's employee who is responsible for implementing, monitoring, and altering, as necessary, the traffic control plan. The Engineer will then advise the local law enforcement agency having jurisdiction, of the names of the contractor's representative and a representative of the Department who will act in a similar capacity. The contractor's designee shall be available at any time to respond to calls involving damage or displacement to barricades, lights, signs and other devices resulting from vandalism, traffic accident or other causes.

If, at any time, the Engineer determines that sufficient traffic control is not being provided or maintained, the Engineer may order suspension of the work until the proper level of traffic control is achieved. In cases of serious or willful disregard for safety of the public or workers by the contractor, the Engineer may proceed to place the traffic control measures in proper condition and deduct the cost thereof from monies due or becoming due the contractor.

All contractor's personnel, equipment, machinery, tools and supplies shall be kept clear of active traffic lanes, except as necessary for the prosecution of the work. The contractor shall promptly remove any material or debris that is spilled or tracked onto the traveled roadway as a result of the prosecution of the work at no additional cost to the Department. Materials, vehicles and parked equipment shall be kept as far from the traveled way as practical. The contractor shall not park equipment or store materials within 30 feet of the edge of a traveled way unless an adequate barrier is present. Equipment may be parked and materials may be stored in the right-of-way only at locations approved by the Engineer.

Any devices provided under this section which are lost, stolen, destroyed or are deemed unacceptable by the Engineer, while their use is required on the project, shall be replaced by the contractor and, except as hereinafter specified for temporary impact attenuators, at no additional cost to the Department. All such devices shall be replaced by the end of the work shift unless otherwise specified.

The Engineer shall be sole judge as to which signs may require embedded posts, portable stands or another type of support.

701-3.02 Maintenance and Protection of Traffic:

All traffic control devices necessary for the first stage of construction shall be properly placed and in operation before any construction is allowed to start. When work of a progressive nature is involved, such as resurfacing a roadway under traffic, the necessary devices shall be moved concurrently with the advancing operation. The use of temporary devices shall not be extended beyond the anticipated duration of one work shift's production.

All traffic control devices shall be kept clean and free from dirt, mud, and roadway grime. Scratches, rips and tears in reflective sheeting shall be promptly corrected by the contractor, as approved by the Engineer.

Temporary pavement markings shall be applied in conjunction with changes in the traffic pattern. Placement of new pavement markings and removal of old markings shall be done immediately when the need for each arises. Temporary markings and devices shall be removed and new roadway marking shall be completed within 24 hours after any changes in traffic pattern unless otherwise directed by the Engineer. Obliteration of the temporary pavement markings shall be in conformance with Subsection 701-3.06 of these specifications.

Types of barricades, supports or devices not specifically described in the MUTCD and associated ADOT Supplement, but which would cause a hazard to traffic if used by the contractor, will not be permitted in the work area. The methods used by a contractor to control traffic when there are no details included in the contract, shall produce a safe condition for travel to the maximum extent possible at all times.

701-3.03 Temporary Concrete Barriers:

Barriers shall be installed in accordance with the details and at the locations shown on the project plans or where directed by the Engineer. Sections of temporary barrier shall be fastened together as shown on Standard Drawing 4-C-2.01 to form a continuous chain. After placement, each unit shall be moved longitudinally to remove slack in the joints between the units. Where shown on the project plans or directed by the Engineer, the ends of the barrier run shall be flared back or fitted with an impact attenuation device. Attenuation devices shall be installed in accordance with the requirements of Subsection 701-3.04 of these specifications.

Barrier Markers shall be installed as shown on the project plans or standard drawings.

Any unit which has been excessively damaged, as determined by the Engineer, shall not be used. Any unit damaged during or after installation shall be replaced with an undamaged unit by the close of that work shift, at no additional cost to the Department.

Temporary Glare Screen shall be installed on barriers at locations shown on plans, and on barriers used to separate opposing traffic on freeway construction contracts in urban areas. When barrier is used on freeway construction to separate traffic from construction operations, glare screen may be required when construction activity is continuous for at least 1,500 feet adjacent to the active traffic lanes.

Temporary Glare Screen shall be expanded metal or plastic attached to the barrier by a method satisfactory to the Engineer. Temporary Glare Screen shall have the following characteristics:

- (1) When hit, the device shall not penetrate the passenger compartment of the errant vehicle or present a hazard to workers and other traffic.

- (2) The device shall perform in a predictable manner when hit.
- (3) The device shall effectively reduce glare from oncoming vehicle head lights.
- (4) The device shall be resistant to vandalism and vehicle damage, and shall be easy to repair.

701-3.04 Temporary Impact Attenuation Devices:

Energy absorbing terminals conforming to the requirements of Subsection 702-2.02 of these specifications shall be installed at the locations and in accordance with the details shown on the project plans and the manufacturer's instructions.

Devices that are damaged by the traveling public shall be repaired within 36 hours by the contractor utilizing a replacement parts package, which shall be on the job site whenever this system is in use. The replacement parts package supplied by the contractor shall be the one recommended by the manufacturer of the attenuation device in use. Upon completion of the work for which energy absorbing terminals are required, all temporary terminals used during the project and the associated replacement parts packages shall be carefully removed and stockpiled by the contractor within the limits of the project at a location specified by the Engineer and shall become the property of the Department.

Sand barrel crash cushions conforming to the requirements of Subsection 702-2.03 of these specifications shall be placed in accordance with the details shown on the project plans.

Crash cushions damaged by the traveling public shall be removed and disposed of by the contractor. New devices shall be furnished and installed by the contractor. The contractor shall repair any damaged installations within 36 hours. Sand barrel crash cushions will remain the property of the contractor upon completion of temporary use unless permanently incorporated into the project.

Upon approval of the Engineer, undamaged attenuation devices, sand barrels or metal type, may be used for permanent installation in accordance with the requirements of Subsections 702-2 and 702-3 of these specifications.

701-3.05 Temporary Pavement Markings (Application and Removal):

(A) General:

Application of temporary pavement markings shall conform to the requirements of Subsection 708-3 of these specifications, the MUTCD and associated ADOT Supplement, and other provisions of these specifications as applicable. Placement of new markings shall be done immediately when the need for each arises, in conjunction with changes in the traffic pattern.

On intermediate lifts of overlay projects, pavement marking for temporary striping shall consist of four-inch wide by four-foot long strips of reflective material, either pavement marking tape or traffic paint, placed at 40-foot intervals. In situations involving severe degree of curvature, the Engineer may direct that the length and spacing be adjusted to two feet and 20 feet, respectively. These requirements apply to white lane lines separating traffic moving in the same direction and to yellow centerlines for two-lane, two-way roadways in areas where passing is permitted. Temporary pavement marking shall be placed on each subsequent pavement course.

Pavement Markings may be required by the Engineer in lieu of barricades for temporary delineation when the duration of use as shown in the traffic control plan may exceed five days or when lane widths are less than 12 feet.

(B) Raised Pavement Markers:

The adhesive shall be applied uniformly to the cleaned pavement surface and the raised pavement marker shall be placed in the correct position on the adhesive area with the application of pressure as specified by the manufacturer.

(C) Preformed Pavement Markings:

Preformed pavement markings for temporary applications shall be Types II (Temporary-Removable) and III (Temporary-Nonremovable) and shall conform to the requirements of Subsection 705-3 of these specifications.

Preformed Pavement Markings, Type II, shall only be used on surfaces or finish pavement courses where eventual removal will be required.

Preformed Pavement Markings, Type III, shall only be used where removal of markings is not required due to obliteration, abandonment or overlaying the pavement surface. Temporary pavement marking paint may also be used where removal of markings is not required unless otherwise shown on the project plans or in the Special Provisions.

701-3.06 Obliteration of Existing Pavement Markings:

Pavement marking obliteration shall be accomplished by the contractor as indicated on the plans or as directed by the Engineer.

Pavement markings shall be removed to the fullest extent possible from the pavement by any method that does not materially damage the surface, color, or texture of the usable pavement. Abrasive blasting, using air or water, is an acceptable method for removing pavement markings, however, other methods may be approved by the Engineer. Overpainting of markings with paint or asphalt will not be permitted.

Sand or other material deposited on the pavement as a result of removing pavement markings shall be removed as the work progresses. Accumulations of sand or other material, which might interfere with drainage or might constitute conditions adverse to traffic safety, shall be removed by the contractor.

Where blast cleaning is used for the removal of pavement markings or for removal of objectionable material, the residue, including dust, shall be removed immediately after contact between the sand and the surface being treated. Such removal shall be by a vacuum attachment operating concurrently with the blast cleaning operation, or by other methods approved by the Engineer. Blast cleaning shall not be used within 12 feet of a lane occupied by public traffic unless a suitable barrier separates traffic from the area being cleaned.

Obliteration or removal of raised pavement markers shall include removal of the marker and adhesive pad, or adhesive pad alone if the marker is missing.

Any damage to the pavement caused by pavement marking removal shall be repaired by methods acceptable to the Engineer. When asphalt slurry is used to repair damage to the pavement caused by pavement marking removal or the obliteration of the marks remaining after the markings have been removed, the asphalt slurry shall be placed parallel to the new direction of travel and shall be at least two feet in width.

If obliteration of lead-based striping is necessary, it shall be accomplished by a method that is in compliance with 29 CFR, Lead Exposure in Construction, Interim Final Rule. If lead exposure prevention measures are required, the contractor shall ensure that all contractor personnel, subcontractors, and ADOT personnel present on the job site are notified of the activity and advised of precautions necessary to avoid contamination by lead compounds. The contractor shall submit a lead exposure plan to the Engineer for review at least 48 hours prior to the start of any striping obliteration activities. Payment for additional work to remove lead-based striping shall be in accordance with Subsections 104.02 or 109.04.

701-3.07 Truck-Mounted Attenuator:

Trucks and truck-mounted attenuators shall be furnished by the contractor at the locations shown on the project plans and/or as directed by the Engineer.

Trucks shall be highway maintenance service trucks weighing between 10,000 and 24,000 pounds. Trucks equipped with truck-mounted impact attenuators shall be furnished with shoulder and lap restraint safety belts for both driver and passenger seats. All truck-mounted attenuators shall meet NCHRP 230 requirements. The attenuators shall consist of three basic components:

- (1) A back-up support structure for attaching the back-up to the truck;
- (2) A back-up; and
- (3) A crushable cartridge containing an energy absorbing material.

The dimensions of the attenuator shall be approximately seven feet long, two feet high and eight feet wide, and the total weight of the attenuator shall be approximately 1,000 pounds.

Attenuators shall have rear-mounted, black and high-intensity yellow chevron stripes and a standard trailer lighting system, including brake lights, turn signals, ICC-bar lights, and two yellow rotating beacons mounted on opposite rear corners of the truck approximately 4-1/2 feet from ground level. When the attenuator is in position, roadway clearance shall be between 10 and 12 inches. The attenuator shall be designed to provide for quick and simple connection to the truck.

When impacted head-on at 45 miles per hour, the truck-mounted attenuator shall perform as follows:

- (1) For impacting vehicles weighing from 1,800 to 4,500 pounds, the average over-all longitudinal deceleration shall be less than 12 g's; the two-foot flail space velocity shall be less than 40 feet per second; and the roll-ahead distance of the truck, with wheels locked and parking brake set, on clean, dry pavement, shall be less than 15 feet.
- (2) For impacting vehicles weighing up to 1,800 pounds, the average over-all longitudinal deceleration shall be less 15 g's; the two-foot flail space velocity shall be less than 40 feet per second; and the roll-ahead distance of the truck, with wheels locked and parking brake set, on clean, dry pavement, shall be less than 10 feet.

The contractor shall keep the attenuator bright and clean for maximum visibility.

The contractor shall cease operations when a truck-mounted attenuator is damaged. The contractor shall not resume operations until the attenuator has been repaired or replaced, unless authorized by the Engineer.

701-3.08 Changeable Message Board:

Changeable message boards shall be furnished and maintained by the contractor at the locations shown on the plans and as specified by the Engineer. The operations and messages programmed into the board controller shall be as directed by the Engineer. The changeable message board shall be a complete and operational portable unit which shall consist of a wheeled trailer with an adjustable, changeable message board, board message controller and self-contained power supply.

The power supply for the changeable message board shall be a fully independent self-contained trailer-mounted system. The power supply shall be either an internal combustion engine generator or batteries which are recharged from a solar panel mounted above the changeable message board.

The message characters shall be delineated by either electromagnetically actuated reflective dots or optically enhanced light emitting diode pixels (LED) operating under the control of a digital computer.

For changeable message boards using electromagnetically actuated reflective dots or for non solar-powered LED changeable message boards, the contractor shall submit, at the

pre-construction conference, a Certificate of Compliance that the message board to be used on this project shall be as described herein.

The Department's Approved Products List (APL) provides a list of approved solar-powered LED changeable message boards which may be used in the performance of this work. For other solar-powered LED changeable message boards, the contractor shall submit, at the pre-construction conference, a Certificate of Compliance that the message board to be used shall be as described herein. Copies of the most recent version of the APL are available on the internet at <http://www.dot.state.az.us/ABOUT/atrc/apl.htm>.

The character formation system and components shall conform to the following requirements:

- (1) The changeable message board shall have a minimum of three separate lines with eight characters per line.
- (2) The changeable message board matrix configuration shall be 35 dots or pixels per character in a five horizontal by seven vertical arrangement of the dots or pixels.
- (3) The dot or pixel size shall be a 2.5-inch high by 1.625-inch wide rectangle (minimum), or equivalent area.
- (4) Each character shall be 18 inches in height and 12 inches in width (minimum).
- (5) The horizontal character separation shall be three inches or more.
- (6) Dot color shall be fluorescent yellow upon activation and flat black when not activated. The LED pixels shall emit amber light upon activation and be dark when not activated.
- (7) The line separation shall be five to 12 inches.
- (8) Changeable message boards shall be protected with a clear lexan-type or equivalent shield that shall not interfere with or diminish the visibility of the sign message.
- (9) The programmable message board shall be capable of displaying moving arrow patterns as one of the operator-selected programs.
- (10) The programmable message board shall be capable of displaying a minimum of three lines of message copy, with a minimum of eight characters per line, in various alphanumeric combinations.
- (11) The message board shall also be capable of displaying a minimum of four messages in sequence, with variable timing in a minimum of quarter-second increments.

- (12) The message board shall be clearly visible and legible from a distance of 800 feet under both day and night conditions. The dot-matrix board shall have an internal illumination system that shall automatically activate under low light conditions to achieve the visibility requirements. The LED-pixel matrix board shall adjust light output (pulse width modulation) to achieve the visibility requirements.
- (13) The power supply achieved from an internal combustion engine generator shall be capable of operating the changeable message board for 72 continuous hours without refueling.
- (14) The power supply achieved from the battery and solar panel recharging system shall have sufficient capacity to operate the changeable message board for a minimum of 20 days without direct sunshine. The solar panel array shall be capable of recharging the batteries such that 2.5 to 3.5 hours of direct sunshine shall provide for a minimum of one 24-hour period of usage. Additionally, the battery recharging controller shall have an ambient temperature sensing device which will automatically adjust the voltage supplied from the solar panels to the batteries. The sensing device shall ensure that the batteries are properly charged in hot or cold weather and shall provide the sign with sufficient power to operate the sign as specified.

When in operation, the changeable message board trailer shall be offset a minimum of eight feet from the nearest traffic lane. Where possible, a 20-foot or more offset shall be used. When positioned on the highway, a minimum of ten 28-inch reflectorized traffic cones shall be set around the sign unit at a spacing of up to 10 feet.

When not in operation, the changeable message board shall be turned away from oncoming traffic.

The changeable message board trailer shall be placed on a level surface and be secured as recommended by the manufacturer and as directed by the Engineer. The contractor shall provide any necessary incidental grading and clearing work required to provide a level surface and clear area for the sign.

701-3.09 Chip Seal Pavement Marker:

Chip Seal Pavement Markers and covers shall be located and placed on the asphaltic concrete prior to any work being started on the chip seal coat, all in a manner as approved by the Engineer.

Immediately after application of the chip seal coat to the roadway pavement, the plastic covers shall be removed, exposing the reflective tape surfaces.

Chip Seal Pavement Markers that are damaged by the contractor shall be replaced by the contractor at no additional cost to the Department.

701-3.10 Sign Sheetings:

All sign sheeting shall be Type II sign sheeting, conforming to AASHTO M 268, unless otherwise shown on the project plans.

701-3.11 Temporary Removal or Covering of Signs:

Where existing signs are not applicable during construction, they shall be removed or have the affected legends covered in place. Unless otherwise stated in the plans, or if a discrepancy exists, the Engineer will approve the method or methods to be used.

Removed signs shall be properly shipped, stored, and handled in accordance with the manufacturer's recommendations and in a manner approved by the Engineer to assure that such signs will continue to be suitable upon reinstallation.

Where temporary removal of a sign or legend is not practical, the sign face may be covered with an opaque porous cloth or fiber material, folded over the sign edges, and secured at the rear of the sign in such a manner that the sign shall not be damaged.

Tape, hardware, ropes, cables, etc., used to secure the covering material shall not touch, place any pressure on, or damage the sign face.

The covering shall be maintained by the contractor until the Engineer directs reactivation of the sign by removal of the coverings or the contract ends.

The contractor shall restore the signs and legends to their previous conditions, as directed by the Engineer. The contractor shall repair any damage to the signs or shall replace the damaged signs, as directed by the Engineer when damage is the result of the contractor's operations.

701-3.12 Temporary Sign Supports:

Temporary Sign supports installed in the ground shall be removed at the completion of the project, the post holes filled and compacted, and the immediate area restored to match the surrounding area.

701-3.13 Flagging Services:

Flagging services shall consist of either civilian, local enforcement officers and their vehicles, or DPS (Department of Public Safety) officers and their vehicles. The Engineer will determine the type of flagger needed, and may adjust the relative number of hours of each type of flagger specified in the traffic control plan.

If available, only DPS officers shall be used on Interstate Highways and Urban Freeways. DPS officers shall also be used on other construction projects except when a local agency has jurisdiction, in which case a local law enforcement officer and vehicle shall be used.

The Engineer will make all the necessary arrangements to procure DPS flagging services. The contractor shall notify the Engineer a minimum of three working days prior to the start of any operation involving DPS officers for flagging.

Procurement of civilian flaggers, or local enforcement officers used for flaggers, will be the responsibility of the contractor.

For operations in which DPS officers are to be used for flagging, the contractor shall be responsible to notify the Engineer a minimum of six hours in advance of any operation which is to be canceled. Should such notification not be received as specified, and DPS officers are dispatched to provide flagging services for the canceled operation, a charge of \$70.00 per DPS officer will be deducted from the monies due the contractor.

In the event that local enforcement officers or DPS officers are temporarily unable to provide flagging services, the contractor shall ensure that traffic control is maintained and all personnel are protected, either by providing civilian flaggers or through other means as approved by the Engineer. No adjustments to the contract will be allowed for any delays resulting from the unavailability of local enforcement officers or DPS officers.

A local enforcement officer shall not work more than 12 consecutive hours unless an emergency situation exists which, in the opinion of the Engineer, requires that the officer remain in the capacity of a flagger.

The contractor shall furnish verification to the Engineer that civilian flaggers have had training in safe flagging procedures.

701-4 Method Of Measurement:

701-4.01 General:

The Department will reimburse the contractor for the work of maintaining and protecting traffic on the basis of unit bid prices for the various Elements of Work. No additional measurement for payment to the contractor will be made for any Elements of Work other than those listed in the bidding schedule.

Elements of Work specified under this subsection which are lost, stolen, destroyed, or are deemed unacceptable by the Engineer, while in use on a project shall be replaced by the contractor and, except as hereinafter specified for temporary impact attenuators, at no additional cost to the Department.

Elements of Work will be measured for payment as follows:

(A) Elements of Work (Complete-in-Place):

The Elements of Work listed herein under Subsection 701-5 will be measured for payment upon the satisfactory completion of the initial installation or obliteration. Except as hereinafter specified under Basis of Payment, no subsequent measurements will be made.

(B) Elements of Work (In Use):

The elements of work listed herein under Subsection 701-6 will be measured for payment from the time at which the element is put into active use on the project and accepted by the Engineer until such time that the Engineer determines that the element is no longer required.

701-4.02 Relocation of Work Elements:

Following the initial installation of an Element of Work described above, the Engineer may direct the contractor to move the Element of Work from one location and reinstall it at another location. Except as specified elsewhere herein, in Subsection 701-5.01 for Temporary Concrete Barrier (Installation and Removal), and Subsection 701-5.02 for Temporary Impact Attenuators (Installation and Removal), no measurement for payment will be made for relocation of Work Elements.

When work of a progressive nature is involved, such as resurfacing a road under traffic, or closing a lane or lanes for work to be accomplished during a shift, no measurement for payment will be made for setting up or relocating the necessary traffic control equipment, workers, devices, facilities, signs etc., that are moved concurrently with the advancing operation, or removal at the end of a shift.

701-4.03 Payment Exceptions:

(A) Deficient Elements of Work:

Any deficiencies in the traffic control plan, devices, equipment, services, or other elements of work listed herein under Subsection 701-4.01(B) will be brought to the attention of the contractor by the Engineer and all deficiencies shall be corrected before the close of that work shift, unless otherwise specified.

The contractor shall not be paid for those deficient Elements of Work listed herein under Subsection 701-4.01(B) unless restored to full usefulness prior to the close of the work shift in which notice of the defect is given, or within the time limits specified in Subsection 701-3. Measurement for payment will not resume until the beginning of the work shift following that work shift in which those elements are restored to usefulness.

(B) Substantial Deficiencies:

For each work day or work shift during which there are, as determined by the Engineer, substantial deficiencies in the contractor's traffic control plan, devices, and/or services, no payment will be made to the contractor for any Element of Work listed herein under Subsection 701-4.01(B).

Measurement for payment will not resume for any Element of Work until the beginning of the work day or work shift following that work day or work shift in which all corrective measures have been performed by the contractor and approved by the Engineer.

In cases of serious or willful disregard for the safety of the public or its employees by the contractor, the Engineer may place the traffic control elements in proper condition and deduct the cost thereof from monies due or becoming due the contractor.

(C) Nondiligent Prosecution of Work:

In the event that the Engineer determines that the contractor's construction operations are not resulting in the diligent prosecution of the work under contract, no payment will be made to the contractor for the Elements of Work listed herein under Subsection 701-4.01(B) until such time as the Engineer determines that the contractor is devoting appropriate efforts toward completion of the work. Payment will be suspended effective with the end of the work day or work shift in which written notice is issued to the contractor by the Engineer notifying the contractor of its failure to prosecute the work. Payment will resume with the beginning of the work day or work shift following that work day or work shift in which the Engineer determines that satisfactory efforts are being made by the contractor toward completion of the work. In any case, the contractor shall continue to be responsible for maintaining all barriers, attenuators, signs, lights and other traffic control devices in proper functioning condition at all times.

(D) Non-Working Periods:

Measurement for payment of the Elements of Work listed herein under Subsection 701-4.01(B) will begin on the day they are installed in place for traffic control and direction. When the elements are not needed for traffic control, they shall be removed or covered and will not be measured unless they are required to stay on site in anticipation of future use or emergency use as determined by the Engineer. Should devices be required on site for these purposes they will be measured and paid for by the unit prices. During non-working periods such as holidays and Sundays, the elements in place and in satisfactory condition will be measured for payment on the day following such downtime. During these non-working periods the contractor shall conduct a minimum of one check per day to verify that the elements are in place and in satisfactory condition.

No payment will be made to the contractor for the Elements of Work listed herein under Subsection 701-4.01(B) for non-working periods resulting from a suspension of work that, in the opinion of the Engineer, is due to the fault of the contractor. In any case, the contractor shall continue to be responsible for maintaining all barriers, attenuators, signs, lights and other traffic control devices in proper functioning condition at all times.

(E) Limitation of Measurement:

Elements of Work listed herein under Subsection 701-4.01(B) that are measured on a unit per day basis will be measured for payment for each 24-hour day. Measurement will be based on the maximum number of units of the specific element of work that are in simultaneous use during any given period regardless of the length of time that the elements are in use and regardless of the number of times the elements are relocated.

Measurement will be made after the initial installation and once weekly thereafter for items in continuous use and at any other times changes are made in the use of traffic control

elements listed under Subsection 702-4.01(B). The contractor shall notify the Engineer when any changes are made in the use or location of traffic control elements.

(F) Expiration of Contract Time:

No reimbursement will be made to the contractor for the Elements of Work listed herein under Subsection 701-4.01(B) when they are required in association with construction work being performed after the expiration of the contract time and all approved extensions.

In any case, the contractor shall continue to be responsible for maintaining all barriers, attenuators, signs, lights and other traffic control devices in proper functioning condition at all times.

701-4.04 Measurement of Work Elements:

Measurement will be made as follows:

- (A) Temporary Concrete Barrier will be measured by the linear foot along the center line of the uppermost surface upon its initial installation (Complete-in-Place). Barrier will be measured by linear foot for each 24-hour day for the "In-Use" condition.
- (B) Temporary Impact Attenuators, such as Sand Barrels and Energy Absorbing Terminals, will be measured by the unit for each complete device upon its initial installation (Complete-in-Place). Temporary Impact Attenuators will be measured by the day for each 24-hour day that a temporary impact attenuator is in place and functional for the "In-Use" condition.
- (C) Truck-Mounted Attenuators, including driver, will be measured by the day for each 24-hour day that a truck-mounted attenuator and operator are used to protect the work site.
- (D) Flashing Arrow Panels will be measured by the day for each 24-hour day that each panel is in place and operating.
- (E) Pilot Vehicles, including driver, will be measured by the hour for each approved hour of operation.
- (F) Civilian flagging services will be measured by the hour for each hour that a civilian flagger is provided. Flagging services by local enforcement officers will be measured for each hour that a uniformed, off-duty law enforcement officer with police vehicle is employed directly by the contractor as a flagger, when authorized in advance by the Engineer. No measurement will be made when DPS officers and their vehicles are used to provide flagging services.

Civilian or local enforcement flagging services and traffic control required to permit contractors' traffic to enter safely into normal traffic within the project limits will be paid under this item. Flaggers required by a written local permit agreement will be measured for payment under this item. Additional civilian or local enforcement flagging services used within the project limits shall be measured for payment under this item, subject to the approval of the Engineer.

Civilian or local enforcement flagging services and traffic control devices used outside the project limits will be measured under this item. The Department will pay 50 percent of the unit bid price for such flaggers and traffic control devices used as described in this paragraph, subject to the approval of the Engineer. The project limits are defined as the construction work zone as shown on the approved traffic control plan for the specific section of highway under construction.

The contractor shall be responsible for obtaining and paying all costs for local enforcement officers and vehicles.

- (G) Temporary Preformed Markings for Pavement, Types II and III, will be measured in accordance with the requirements of Subsection 705-4 of these specifications.
- (H) Temporary Painted Markings for Pavement will be measured in accordance with the requirements of Subsection 708-4 of these specifications.
- (I) Obliterate Pavement Marking will be measured in accordance with the requirements of Subsection 708-4 of these specifications.
- (J) Changeable Message Boards will be measured by the day for each 24-hour day that the sign is utilized to maintain and control traffic.
- (K) Obliterate Pavement Markers will be measured for each unit, Markers and Adhesive pad, or Adhesive pad alone where Markers are missing.
- (L) Temporary Delineators (Standard Drawing 4-M-4.01) and Temporary Pavement Markers will be measured as a unit for each delineator and marker furnished, utilized, and subsequently removed from the project site. No measurement for payment will be made for delineators and markers that are furnished to replace damaged units as specified under Subsection 701-4.01.
- (M) Vertical Panels, Barricades (Types II and III), Tubular Markers, Warning Lights (Types A, B, and C), Traffic Cones (28-inch), High-Level Flag Trees, Drums, Embedded Sign Posts, and Portable Sign Stands (Spring-Type and Rigid), will be measured as a unit for each device furnished and subsequently utilized at the project site for each 24-hour day.

Temporary Signs will be measured as Small (less than 10 square feet) with either Type II or Type III/IV sheeting, and Large (10 square feet or more) either Type II or Type III/IV sheeting. Temporary Signs will be measured as a unit for each sign furnished and subsequently utilized at the project site for each 24-hour day. Quantities may be determined on a weekly basis for signs in continuous use.

Utilization shall be defined as including those devices ordered to remain on site or covered in accordance with Subsection 701-4.03(D) and approved by the Engineer.

- (N) Specialty Signs are signs which are required on the job, as determined by the Engineer or shown on project plans, and are not reusable as traffic control signs. Specialty Signs shall contain information which is project and location specific. The sign sheeting shall be Type II; and the size, type and legend of the Specialty Signs will be determined by the Engineer, unless specified on the project plans. Specialty Signs will be measured for payment by the square foot, inclusive of borders. Any sign over 20 square feet in area shall be considered a Specialty Sign.
- (O) Obliterate Pavement Legends or Arrows will be measured by each separate symbol, arrow or legend.

701-5 Basis of Payment for Elements of Work (Complete-in-Place):

701-5.01 Temporary Concrete Barrier (Installation and Removal):

Temporary concrete barrier, measured as provided above, will be paid for at the contract unit price, which price shall be full compensation for the work, complete, as specified herein and as shown on the plans, including furnishing, placing, dismantling, and removal. The price bid shall also include any required connection devices, barrier markers, and glare screen.

Should it be necessary to dismantle, pick up and relocate a portion of the barrier installation a lateral distance of more than 12 feet during construction, that portion of the removed and relocated barrier will be considered a new installation and measured for payment at the contract unit price.

For a lateral movement of 12 feet or less, or any vertical movement, the contractor will be paid for 50 percent of the length of the relocated Temporary Concrete Barrier (Installation and Removal), provided the contractor can demonstrate, to the Engineer's satisfaction, that it is not possible to move the barrier without dismantling and lifting. No payment will be made for portions of the barrier which the contractor can relocate without dismantling and picking up.

701-5.02 Temporary Impact Attenuators (Installation and Removal):

Temporary Impact Attenuation Devices shall include Sand Barrels and Energy Absorbing Terminals, measured as provided above, and paid for at the contract unit price, which price shall be full compensation for the work complete in place, as specified herein and as shown on the plans, including furnishing the devices with replacement parts, installing, removing and stockpiling the devices.

Should it be necessary to dismantle, pick up and reinstall attenuation devices during construction, for use on the project site, the work of removing and reinstalling the devices will be measured for payment as a new installation.

The Engineer will be the sole judge as to whether devices are to be dismantled, picked up and reinstalled or are to be adjusted or realigned.

Measurement and payment for furnishing materials, equipment and labor and repairing attenuation devices that are damaged by the traveling public will be made in accordance with the requirements of Subsection 109.04 of these specifications.

No measurement or direct payment will be made for furnishing replacement parts and repairing devices damaged by other than the traveling public.

701-5.03 Temporary Preformed Markings for Pavement:

The accepted quantities of Temporary Preformed Markings, measured as provided above, will be paid for at the unit bid price for the type specified, which price shall be full compensation for the work, complete in place, including necessary pavement cleaning, and maintaining Types II and III temporary markings in construction work zones. Installation for accepted quantities shall be considered satisfactory when the markings are installed in conformance with the requirements of the plans.

When the type of temporary preformed marking is not specified, the contractor shall furnish Type II.

Additional reimbursement will be made for replacement of Temporary Markings when the contractor is required by the Engineer to install marking materials on distressed pavements or during adverse weather conditions and subsequent failure occurs. Distressed pavement conditions are defined as alligator cracking, bleeding, or spalling of bituminous pavements and spalling of PCC pavements. Adverse weather conditions are defined as any occurrence where application is required at pavement temperatures less than 50 degrees F or when precipitation occurs within 24 hours before application. The Department will pay for the replacement, where failures occur, at the unit bid price for the items. In the event a second failure occurs when markings have been reapplied on distressed pavements or under weather conditions described above, the Engineer shall determine if conditions require primer, alternate methods of marking, or reapplication of Preformed Markings. Preformed markers and markings will be paid for at the unit bid price. Primers or other methods of markings deemed necessary by the Engineer will be paid for in accordance with the provisions of Subsection 109.04 of these specifications.

701-5.04 Temporary Painted Pavement Markings:

The accepted quantities of Temporary Painted Markings, Symbols, Arrows, and Legends, measured as provided above, will be paid for at the unit bid price for the type specified, which price shall be full compensation for the work, complete in place, including glass beads.

701-5.05 Obliterate Pavement Marking:

Obliterate Striping, measured as provided above, will be paid for at the unit bid price per linear foot, which price shall be full compensation for the work, complete, including furnishing all labor and equipment required and restoring the pavement surface to a condition acceptable to the Engineer.

The accepted quantities of Arrows, Symbols, or Legends obliterated shall be paid for at the unit bid price for each item.

701-5.06 Temporary Pavement Markers and Chip Seal Pavement Markers:

The accepted quantities of Temporary Pavement Markers and Chip Seal Pavement Markers measured as provided above will be paid for at the unit bid price each, which price shall be full compensation for the work, complete in place, as specified herein and as shown on the plans.

701-5.07 Obliterate Pavement Markers:

Obliterate Pavement Markers will be paid for at the unit bid price each, which price shall be full compensation for the work, complete, including adhesive pad.

701-5.08 Temporary Delineators (Standard Drawing 4-M-4.01):

The accepted quantities of Temporary Delineators, measured as provided above, will be paid for at the unit bid price each, which price shall be full compensation for the work, complete, including subsequent removal as specified herein and as shown on the plans.

701-5.09 Specialty Signs:

The accepted quantities of Specialty Signs, measured as provided above, will be paid for at the unit bid price per square foot which price shall be full compensation for the work, complete in place, including manufacturing, delivery to the job site, erection and eventual removal. The price paid shall also include the cost of flags, ballasting, mountings, sign stands, and embedded posts as required.

701-5.10 Temporary Removal or Covering of Signs:

No payment will be made for Temporary Removal or Covering of Signs, including maintenance of storage facilities for the signs or sign legends and the maintenance of sign coverings, the cost being considered as included in the price of contract items.

701-6 Basis of Payment for Elements of Work (In Use):

701-6.01 Quantity Variances:

Payment for variances in quantities shall be in accordance with Subsection 104.02, except that, for decreases in quantities, the following items will be considered as major items:

- (1) Temporary Concrete Barrier (In-Use);
- (2) Barricades; and
- (3) Temporary Signs.

701-6.02 Temporary Concrete Barrier (In Use):

The accepted quantities of Temporary Concrete Barrier, measured as provided above, will be paid for at the unit bid price, which price shall be full compensation for the use of the barrier installation(s), including glare screen, and for furnishing all material, equipment and labor and maintaining, realigning and adjusting the barrier installation(s), as specified herein and as shown on the plans. No payment will be made for barrier not in service, such as, barrier in stockpiled configuration awaiting phase construction change.

There will be no payment for each day that the Engineer determines the barrier traffic reflectors are not in good reflective condition, or for each day that the Engineer determines the barrier is out of alignment.

701-6.03 Channelization Devices:

(A) Vertical Panels, Barricades (Type II), Traffic Cones (28-inch), and Tubular Markers:

The accepted quantities of Vertical Panels, Barricades (Type II), Traffic Cones (28-inch), and Tubular Markers, measured as provided above, will be paid for at the unit bid price, which price shall be full compensation for the use and maintenance of each device (in-use), including labor and equipment.

Type I barricades which are substituted for Type II barricades in accordance with Subsection 701-2.08 shall be paid for at the unit bid price for Type II barricades.

The unit bid price for barricades includes the cost of ballasting as required.

(B) Barricades (Type III) and High-Level Flag Trees:

The accepted quantities of Barricades (Type III) and High-Level Flag Trees, measured as provided above will be paid for at the unit bid price, which price shall be full compensation for the use and maintenance of each device (in-use), including labor and equipment.

The unit bid price for barricades includes the cost of ballasting and flags, as required.

When signs are to be mounted on Barricades (Type III) or High-Level Flag Trees, the signs will be paid for as Temporary Signs, Section 701-6.04.

(C) Drums:

The accepted quantities of Drums, measured as provided above, will be paid for at the unit bid price, which price shall be full compensation for the use and maintenance of each device (in-use), including labor and equipment.

Drums shall conform to Standard Drawing 4-M-2.07, and shall be included on the list of pre-approved products maintained by the Department or be an alternate plastic drum approved by the Engineer.

(D) Warning Lights (Types A, B, and C):

The accepted quantities of Warning Lights (Types A, B, and C), measured as provided above, will be paid for at the unit bid price, which price shall be full compensation for the use and maintenance of each device (in-use), including labor and equipment.

(E) Embedded Sign Posts, Portable Sign Stands (Spring-Type or Rigid) and Portable Sign Posts-Barrier Mounted:

The accepted quantities of Embedded Sign Post, Portable Sign Stands (Spring-Type and Rigid) and Portable Sign Posts-Barrier Mounted, measured as provided above will be paid for at the unit bid price, which price shall be full compensation for the use and maintenance of each device (in-use), including labor and equipment.

The unit bid price for signs includes the cost of ballasting as required.

701-6.04 Temporary Signs:

The accepted quantities of Temporary Signs, measured as provided above, will be paid for at the unit bid price, which price shall be full compensation for the use and maintenance of each device (in-use), including labor and equipment.

The unit bid price for signs includes the cost of flags and ballasting as required.

No separate payment shall be made for speed plates, distance plates, or other minor sign message boards that are attached to a temporary sign, or temporary sign post, as shown on the plans. If additional signs are attached to those shown on the plans or to existing temporary sign installations, payments will be made as additional temporary signs.

701-6.05 Truck-Mounted Attenuators:

The accepted quantities of truck-mounted attenuators, measured as provided above, will be paid for at the unit bid price per day of work site protection, which rate shall be full compensation for the work, complete, including, but not limited to, furnishing all materials,

equipment and labor (including the operator) and maintaining and repairing the truck and truck-mounted attenuator as specified herein and on the project plans. It shall be the contractor's responsibility to replace any damaged or destroyed parts of the attenuator at no additional cost to the Department.

701-6.06 Flashing-Arrow Panels, and Changeable Message Boards:

The accepted quantity of flashing-arrow panels, measured as provided above, will be paid for at the unit bid price, which price shall be full compensation for the work, complete, including furnishing, operating, maintaining, and relocating the panels on the work site, and providing all necessary labor and equipment.

The accepted quantities of Changeable Message Boards, measured as provided above, will be paid for at the unit bid price per day, which price shall be full compensation for the work, complete, including incidental grading; traffic cones; and furnishing, operating, maintaining, and relocating the boards on the work site, and providing all necessary labor and equipment. No payment will be made for incidental grading or traffic cones, the cost being considered a part of contract items.

701-6.07 Pilot Services, and Flagging Services:

The accepted quantities of pilot and relocation service trucks, measured as provided above, will be paid for at the unit bid price, which price shall be full compensation for the work, complete, including, but not limited to, furnishing and maintaining the vehicle and furnishing the pilot truck driver. Overtime hours for pilot services worked will be paid at a rate determined by multiplying the straight-time hours times a factor of 1.35.

Basis of payment for a local enforcement officer, including vehicle, used as a flagger will be in accordance with the following:

Hours Per Day	Pay Rate
First eight hours	straight time
Hours nine through twelve	time and one half
Over 12 hours	double time

Overtime hours will be converted into straight-time hours for measurement.

The accepted quantities of flagging services provided by civilian flaggers, measured as provided in Subsection 701-4.04(F), will be paid for at the unit bid price, which price shall be full compensation for the work, complete, including all overhead costs and fringe benefits.

No payment will be made when DPS officers and their vehicles are used to provide flagging services.

701-6.08 Temporary Impact Attenuators (In-Use):

The accepted quantities of temporary impact attenuators, measured as provided above, will be paid for at the unit bid price, which price shall be full compensation for the use of the

complete attenuating device and for furnishing all material, equipment and labor for maintaining, realigning and adjusting the attenuator installation, as specified herein and as shown on the plans. No payment will be made for attenuators not in service, such as attenuator stockpiled for replacement parts or awaiting phase construction change.

SECTION 702 ATTENUATION DEVICES:

702-1 Description:

The work under this section shall consist of furnishing all materials and installing attenuation devices of the types and at the locations and in accordance with the details shown on the project plans and the requirements of these specifications.

702-2 Materials:

702-2.01 General:

Materials used in the construction of the vehicular impact attenuator system shall all be new except that undamaged attenuation devices used for Maintenance and Protection of Traffic may be used for permanent installation when approved by the Engineer.

Materials used in transitions or connections between impact attenuators and metal-beam guardrail shall conform to the requirements of Section 1012.

Materials used in transitions or connections between impact attenuators and concrete structures or barriers shall conform to the applicable requirements of Subsection 910-2, except anchors and anchor bolts shall conform to the requirements of Section 1012.

Concrete shall be utility concrete conforming to the requirements of Section 922. Steel reinforcement shall conform to the requirements of Section 1003.

Asphaltic concrete shall conform to the requirements of Section 406.

Attenuation devices approved for use are shown on the Department's Approved Products List (APL). The most current version is available on the internet at <http://www.dot.state.az.us/ABOUT/atrc/apl.htm>. Attenuation devices other than those listed on the APL shall be approved by the Department prior to use.

702-2.02 Energy-Absorbing Terminal:

Energy-absorbing terminals shall be multiple bin units of collapsible cartridges positioned between diaphragms that are enclosed by a framework of the beam guardrail fender panels conforming to the details shown on the project plans.

702-2.03 Sand Barrel Crash Cushion:

Sand barrel crash cushions shall be frangible, plastic modules formulated or processed to resist deterioration from ambient ultraviolet rays. The color of the outer module or stabilizer and lids shall be the standard gray or yellow color as furnished by the vendor.

The modules shall exhibit good workmanship free from structural flaws and objectionable surface defects. The Engineer may measure the thickness of the inner module and stabilizer walls as shown on the plans by any means the Engineer considers appropriate. When filled with the specified weight of sand, the module walls shall not distort, either as an indentation or a protrusion, more than 1/2 inch from the original module wall configuration.

Modules shall be filled to the designated height with sand (fine aggregate) meeting the requirements of Subsection 1006-2.03 (B). The sand, when placed in the module, shall have a dry unit weight of from 80 to 105 pounds per cubic foot and a moisture content of less than two percent, by weight.

Sand barrel crash cushion installations at elevations above 3,000 feet shall have five percent rock salt (by weight) mixed with the sand.

702-3 Construction Requirements:

Attenuation devices shall be placed at the locations shown on the project plans or as directed by the Engineer and shall conform to the details shown on the plans and the requirements of the manufacturer.

Unless otherwise specified on the project plans, when the plans require the attenuation device to be placed on a paved pad, the pavement shall be four inches thick and shall be made either of utility concrete or asphaltic concrete, at the option of the contractor. The soil under the pad, or under the impact attenuator when no pad is required, shall be compacted to not less than 95 percent of the maximum density found in accordance with the applicable test methods of the ADOT Materials Testing Manual, as directed and approved by the Engineer. When installation of the attenuation device is complete, all trash shall be removed from its area and the soil surface around it shall be smoothed to the elevation indicated on the project plans.

Any welding required shall be performed in accordance with the requirements of the American Welding Society Structural Welding Code AWS D 1.1-80.

702-4 Method of Measurement:

Attenuation devices will be measured as a unit for each device installed, except that devices which were previously used for maintenance and protection of traffic and are being reused as a permanent installation will not be measured for payment.

702-5 Basis of Payment:

The accepted quantities of attenuation devices, measured as provided above, will be paid for at the contract unit price for the type designated in the bidding schedule, complete in place. No extra measurement or payment will be made for any concrete, reinforcing steel,

hardware, fasteners, structural steel, pavement pad materials, any connection or transition section needed to connect the impact attenuator to guardrail or concrete barriers, grading in the area of the impact attenuator and required only to smooth vehicle approach paths to it, excavation and backfill required immediately adjacent to the barrier, and sand to fill crash cushion modules, as the cost thereof will be considered as included in the contract unit price for the impact attenuator, complete in place.

Labor and equipment used to remove and reinstall attenuation devices used for maintenance and protection of traffic and being reused as a permanent installation will be paid for in accordance with the provisions of Subsection 109.04.

SECTION 703 DELINEATORS AND MARKERS:

703-1 Description:

The work under this section shall consist of furnishing and installing delineators, reference markers, object markers, snow markers and milepost markers in conformance with the details shown on the plans and in accordance with the requirements of these specifications.

The types of delineators and markers to be installed and the locations will be shown on the project plans.

703-2 Materials:

703-2.01 General:

Certificates of Compliance conforming to the requirements of Subsection 106.05 shall be submitted.

703-2.02 Metal Posts:

Posts for delineators and for all markers, including mileposts or reference markers installed on freeways shall conform to the details shown in the project plans.

703-2.03 Concrete:

Concrete for the milepost or reference marker foundations shall be utility concrete conforming to the requirements of Section 922.

703-2.04 Metal Plates:

Metal plates for the various types of object markers shall conform to the details shown on the plans and shall be fabricated in one piece from 0.063-inch thick aluminum-alloy sheet 3003-H 14, 5052-H 38, or 6061-T 6, all conforming to the requirements of ASTM B 209.

703-2.05 Paint:

Paint for use on the metal plates shall conform to the requirements of Section 1002 for the type and color of paint specified on the plans.

703-2.06 Retroreflective Sheeting:

Retroreflective sheeting for delineators and markers shall conform to the requirements of Section 1007.

The type of retroreflective sheeting to be applied shall be as specified on the plans.

703-2.07 Prismatic Reflectors:

Prismatic reflectors for delineators and markers shall conform to the requirements of Section 1008.

The type of prismatic reflectors to be used shall be as specified on the plans.

703-2.08 Hardware:

Steel bolts and nuts of the types shown on the plans shall be galvanized in accordance with the requirements of ASTM A 153 or shall be cadmium plated in accordance with the requirements of ASTM B 766.

703-3 Construction Requirements:

Metal posts shall be cut and perforated to the sizes and shape shown on the plans. The finished posts shall be straight with a permissible tolerance in straightness of 1/16 inch per three (3) feet of post length.

Posts on which galvanizing has been damaged in transporting, handling or erecting shall be repaired by the contractor at its expense in accordance with the requirements of Subsection 610-3.06.

Metal plates shall be cut to size and shape and the holes punched for mounting all in accordance with the details shown on the plans. The surfaces and edges of the plates shall be free of buckles, warps, dents, cockles, burrs, and defects resulting from fabrication.

Posts shall be set vertically to line at the locations designated on the plans. Posts, except mileposts or reference marker posts requiring concrete foundations, shall be set firmly in the ground by a method that will not bend the post or deface the top of the post. If ground conditions are such that the posts cannot be driven without damaging the posts, pilot holes shall be required. Metal plates shall be installed after the posts have been set in place.

Posts shall be placed in the ground to the depth shown on the plans.

Foundations for the milepost or reference marker posts installed on freeways shall be constructed to the details and dimensions shown on the project plans. Excavation shall conform to the requirements of Subsection 203-5.03(A).

Existing markers and delineators that are to remain in place and which have been damaged by the contractor shall be replaced with new ones at its expense.

703-4 Method of Measurement:

Delineators and markers will be measured by the unit for each type of delineator and marker furnished and installed.

703-5 Basis of Payment:

The accepted quantities of delineators and markers, measured as provided above, will be paid for at the contract price each for the type of delineator or marker designated in the bidding schedule, which price shall be full compensation for the work complete in place.

SECTION 704 THERMOPLASTIC PAVEMENT MARKINGS:

704-1 Description:

The work under this section shall consist of cleaning and preparing pavement surfaces and furnishing and applying either white or yellow thermoplastic reflectorized pavement markings using extrusion, ribbon or spray dispensing devices of the required shape and thickness to the prepared pavement surface at the locations and in accordance with the details shown on the project plans, the manufacturer's specifications, and the requirements of these specifications.

704-2 Materials:

704-2.01 General Requirements:

The thermoplastic reflectorized material shall consist of a solid mixture of heat-stable resins, white or yellow pigment, inter-mixed glass beads, filler, and other materials in granular or block form specifically compounded for reflectorized pavement markings to be applied to the pavement in a molten state. The characteristics of the liquefied material shall be such that complete and even coverage of specified areas to the required thicknesses is provided by the required application method and rate. Upon cooling to normal pavement temperature, this material shall produce an adherent reflectorized marking capable of resisting deformation and wear in the roadway.

Only thermoplastic materials currently shown on the Department's Approved Products List (APL) shall be used. Copies of the most recent version of the APL are available on the internet at <http://www.dot.state.az.us/ABOUT/atrc/apl.htm>.

704-2.02 Composition:

The thermoplastic composition shall conform to the following requirements:

	Percent by Weight	
	White	Yellow
Binder (hydrocarbon or alkyd)	18 - 26	18 - 26
Titanium dioxide	10 - 15	-----
Basic lead chromate	-----	2 - 10
Reflective glass inter-mix beads	30 - 40	30 - 40
Calcium carbonate or equivalent filler	20 - 40	25 - 45

The ingredients of the thermoplastic composition shall be thoroughly mixed and in a solid or sectionalized block, or free-flowing granular form. When heated in a melting apparatus, the material shall readily liquefy into a uniform solution. This solution shall be free from all skins, dirt, foreign objects or any other ingredient which would cause bleeding, staining, blotting, or discoloration when applied to the bituminous or concrete pavement surfaces.

The thermoplastic shall be one of the following two types based on the binder composition:

Hydrocarbon: Shall consist mainly of synthetic petroleum hydrocarbon resins with appropriate fillers and pigments.

Alkyd: Shall consist of a mixture of synthetic resins, at least one of which is solid at room temperature, and of high-boiling-point plasticizers. At least one third of the binder composition and no less than eight percent by weight of the entire material formulation shall be solid maleic-modified glycerol ester resin. The alkyd binder shall not contain any petroleum-based hydrocarbon resins.

An alkyd thermoplastic formulation shall be used for all symbols, legends, and transverse lines, including stop bars and crosswalks. Either an alkyd or hydrocarbon thermoplastic formulation may be used for longitudinal lines, including lane lines and edge lines, unless otherwise shown on the project plans or specified herein. Extrusion or spray formulations shall be used in accordance with requirements of the application equipment used to install the markings.

(A) Reflective Glass Beads:

In addition to incorporating glass beads in the thermoplastic mix, glass beads shall be evenly applied to the surface of the molten material, immediately after application, at a minimum rate of 10 pounds of glass beads per 100 square feet of line (300 linear feet of four-inch stripe).

(B) Filler:

The filler shall be a white calcium carbonate or equivalent filler with a compressive strength of at least 5,000 pounds per square inch.

(C) Titanium Dioxide:

Titanium Dioxide shall conform to the requirements of ASTM D 476 for Type II (92 percent).

(D) Lead Chromate Pigment:

The lead chromate pigment shall be silica double encapsulated heat resistant lead chromate pigment.

704-2.03 Physical Characteristics of the Composition:

(A) General Requirements:

The thermoplastic material shall not exude fumes which are toxic, injurious, or require specialized breathing apparatus when heated to the temperature range specified by the manufacturer for application. The material shall remain stable when held for four hours at this temperature, or when subjected to four reheatings, not exceeding a total of four hours, after cooling to ambient temperature. The temperature viscosity characteristics of the plastic material shall remain constant throughout the reheatings and shall show like characteristics from batch to batch. There shall be no obvious change in color of the thermoplastic material as a result of reheating, and the color of the material shall not vary from batch to batch.

(B) Color:

The thermoplastic material, after heating for four hours \pm five minutes at $425 \pm$ three degrees F and cooled to $77 \pm$ three degrees F, shall meet the following:

White: Daylight reflectance at 45 degrees - 0 degrees shall be 70 percent minimum.

Color shall match Federal Test Standard Number 595, color chip no. 17925.

Yellow: Daylight reflectance at 45 degrees - 0 degrees shall be 43 percent minimum.

Color shall match Federal Test Standard Number 595, color chip no. 13538.

(C) Retroreflectance:

The white and yellow thermoplastic materials shall have the following minimum retroreflectance values at 86.5 degrees illumination angle and 1.5 degrees observation angle as measured by a MiroLux 12 portable retroreflectometer or similar approved device within 30 days after application to the roadway surface:

Product	Retroreflectance (millicandelas)
White	200
Yellow	125

(D) Softening Point:

After heating the thermoplastic material for four hours \pm five minutes at $425 \pm$ three degrees F and testing in accordance with ASTM D 36, the thermoplastic materials shall have a softening point of 215 ± 15 degrees F.

(E) Water Absorption and Specific Gravity:

The thermoplastic material shall not exceed 0.5 percent by weight of retained water when tested in accordance with the requirements of ASTM D 570.

The specific gravity of the material, as determined by Section 11 of AASHTO T 250, shall be between 1.85 and 2.3.

(F) Impact Resistance:

After heating the thermoplastic material for four hours \pm five minutes at $425 \pm$ three degrees F and forming test specimens, the impact resistance shall be not less than 10 inch-pounds when tested in accordance with Section 9 of AASHTO T 250.

(G) Bond Strength:

After heating the thermoplastic material for four hours \pm five minutes at $425 \pm$ three degrees F, the bond strength to Portland cement concrete shall be not less than 180 pounds per square inch. The bond strength shall be determined in accordance with the procedures specified in Section 7 of AASHTO T 250.

(H) Abrasion Resistance:

The abrasion resistance of the thermoplastic material shall be determined by forming a representative lot of the material at a thickness of 0.125 inches on a four-inch square monel panel (thickness 0.050 ± 0.001 inches), on which a suitable primer has been previously applied, and subjecting it to 200 revolutions on a Taber Abraser at 25°C , using H-22 calibrated wheels weighted to 250 grams. The wearing surface shall be kept wet with distilled water throughout the test.

The maximum loss of thermoplastic material shall be 0.5 grams.

(I) Cracking Resistance at Low Temperature:

After heating the thermoplastic material for four hours \pm five minutes at $425 \pm$ three degrees F, applying to concrete blocks, and cooling to $15 \pm$ three degrees , the material shall show no cracks when observed from a distance exceeding 12 inches. Testing for low temperature crack resistance shall be in accordance with the procedures specified in Section 8 of AASHTO T 250.

(J) Flowability:

After heating the thermoplastic material for four hours \pm five minutes at $425 \pm$ three degrees F, and testing for flowability in accordance with Section 6 of AASHTO T 250, the white thermoplastic shall have a maximum percent residue of 18, and the yellow thermoplastic shall have maximum percent residue of 21.

(K) Yellowness Index:

The white thermoplastic material shall not exceed a yellowness index of 0.12 when tested in accordance with Section 4 of AASHTO T 250.

(L) Flowability (Extended Heating):

After heating the thermoplastic material for eight \pm 1/2 hours at $425 \pm$ three degrees , with stirring the last six hours, and testing for flowability in accordance with Section 12 of AASHTO T 250, the thermoplastic shall have a maximum percent residue of 28.

(M) Flash Point:

The thermoplastic material shall have a flash point not less than 475 degrees F when tested in accordance with the requirements of ASTM D 92.

(N) Storage Life:

The materials shall meet the requirements of this specification for a period of one year from the date of manufacture. The month and year of manufacture shall be clearly marked on all packages of thermoplastic material. The thermoplastic material must also melt uniformly with no evidence of skins or unmelted particles for this one year period. Any material which does not meet the above requirements, or which is no longer within this one year period at the time of application, shall not be used. The contractor shall replace any outdated material with material meeting the above performance and time requirements at no additional cost to the Department.

(O) Primer-Sealer:

Primer-sealers shall be used on Portland cement concrete, or existing hot mix asphaltic concrete surfaces prior to application of the thermoplastic material, and shall be applied as recommended by the thermoplastic material manufacturer. The primer-sealer shall be compounded specifically for use with the specified thermoplastic material.

Application of primer-sealer will not be required on newly placed hot-mix asphaltic concrete surfaces prior to application of the thermoplastic material.

704-2.04 Physical Requirements for Glass Beads:

Inter-mix and drop-on reflective glass beads shall conform to the requirements of Subsection 708-2.02, except as noted herein.

The inter-mix beads shall conform to AASHTO M 247-81 (1986), type I, and may be coated or uncoated as recommended by the manufacturer. If uncoated beads are used, the thermoplastic formulation shall be configured to minimize settling of the intermix beads when the material is heated and applied.

If recommended by the manufacturer, the drop-on beads shall have an adherence coating.

704-3 Construction Requirements:

704-3.01 Equipment:

The equipment used to install hot applied thermoplastic material shall be constructed to provide continuous uniform heating to temperatures exceeding 400 degrees F while mixing and agitating the material. The heating mechanism of the kettle shall be equipped with a heat transfer medium consisting of oil or air. The burner flame shall not directly contact the material vessel surface. The mixing and agitating mechanism shall be capable of thoroughly mixing the material at a rate which ensures constant uniform temperature distribution. The kettle shall be equipped with two temperature gauges: one to indicate the temperature of the oil or air heat transfer medium, and the other to indicate the temperature of the thermoplastic material. The kettle shall also be equipped with an automatic thermostatic control device that allows for positive temperature control to prevent overheating or underheating of the material.

The conveying portion of the equipment, between the kettle and the line dispensing device shall be configured to prevent accumulation and clogging, and shall maintain the material at the specified application temperature. The dispensing device shall be capable of applying the required shapes and thicknesses. All parts of the equipment which will come in contact with the material shall be constructed for easy accessibility for cleaning and maintenance.

All melting and application equipment shall have functioning and calibrated temperature sensing devices to verify that temperature requirements are being met. The contractor shall provide proof that the temperature sensing devices and verification thermometers are fully functional.

The application equipment to be used on roadway long line installations shall consist of either truck-mounted units or motorized ride-on equipment. The truck-mounted or motorized ride-on units used for center lines, lane lines, gore lines, and edge lines shall consist of a mobile self-contained unit carrying its own material capable of operating at a minimum speed of five miles per hour while applying striping, and shall be sufficiently maneuverable to install curved and straight lines, both longitudinally and transversely.

The truck shall be equipped with high pressure air spray jets in front of the pavement marking material applicators to remove loose matter from the pavement surface where the marking material is to be applied.

Hand applicator equipment, to be used for all other roadway installations, shall be either self-contained melter application units or reservoir application units that are filled from a separate melter unit. Both types of units shall be equipped to maintain and measure the

required application temperatures. The hand applicator equipment shall be sufficiently maneuverable to install symbols and legends, and curved and straight lines, both longitudinally and transversely.

The application equipment shall be so constructed as to assure continuous uniformity in the dimensions of the pavement marking. The applicator shall provide a means for cleanly cutting off square pavement markings edges and provide a method of applying "skip" and solid lane lines. The equipment shall be constructed to provide varying widths and thicknesses of pavement markings. The application equipment shall be mobile and maneuverable to the extent that straight lines can be followed and normal curves can be made in a true arc. The equipment operator shall be located in such a position as to enable full visibility of the striping apparatus.

A glass bead top dressing shall be applied to the completed thermoplastic stripe by an automatic glass bead dispenser attached to the striping machine in such a manner that the beads are applied to the molten thermoplastic material immediately after it has been applied to the pavement. The bead dispenser shall use pressure-type spray guns for truck-mounted or motorized ride-on units, and a drop-on bead dispenser for hand applicators. The bead dispenser shall be capable of evenly distributing glass beads at the required application rate immediately after the application of the thermoplastic. The bead dispenser shall dispense the beads in such a manner that they shall be embedded in the surface of the molten thermoplastic to an anchoring depth of from 55 to 60 percent of the bead diameter. The bead dispenser shall be equipped with an automatic cut-off which is synchronized with the cut-off of the thermoplastic material.

The heating kettle and application equipment shall meet the requirements of the National Fire Underwriters, the National Fire Protection Association, and other applicable federal, state and local authorities. Thermoplastic melting units, trucks or trailers, shall be equipped with foam-type fire extinguishers suitable for application to thermoplastic material that is at the flash point.

704-3.02 Application:

(A) Placement Locations:

Pavement markings shall be positioned as defined on the plans and in the specifications. When it becomes necessary for proper installation, the Engineer may revise individual marking locations as necessary to accommodate the following requirements:

Marking lines shall not be placed on parallel construction or expansion joints. Longitudinal lines shall be offset to provide two to four inches of clearance from parallel construction and expansion joints unless directed otherwise by the Engineer.

Placement of symbols and legends on construction joints, expansion joints or uneven pavement surfaces shall be avoided. Where the location of construction joints, expansion joints or otherwise unsuitable surfaces conflicts with specified locations for symbols or legends, the Engineer will designate the symbol or legend location. The contractor shall identify such location conflicts for the Engineer's determination.

(B) Materials Selection and Compatibility:

All thermoplastic material, drop-on glass beads, and primer-sealer will be inspected and approved by the Engineer prior to their application. The contractor shall also provide samples of said materials if requested by the Engineer.

All materials shall be properly packaged and stored. Each container to be used on the project shall be clearly labeled to indicate the following information:

- Nature, type, and formulation of the material, including whether it is an alkyd or hydrocarbon;
- Manufacturer, batch number, and date of manufacture;
- Application requirements and constraints; and
- Compatibility requirements and constraints, particularly those pertaining to equipment, storage, and other materials to be used.

Preparation and application equipment shall be in accordance with the plans and specifications, and shall conform to the recommendations of the materials manufacturer.

Incompatible materials shall not be used together. The contractor shall not combine alkyd and hydrocarbon materials in preparation or application equipment. The contractor shall completely clean preparation and application equipment when materials are changed.

The contractor shall dispose of excess materials, cleaning fluids, and all empty material containers at a site approved by the Engineer.

(C) Equipment Inspections and Deficiencies:

The contractor shall make daily maintenance and operation inspections of all application equipment to ensure that it is operable within the requirements of the specifications. The contractor shall inform the Engineer of any equipment breakdowns, intermittent malfunctions, or other conditions that may impact the proper application of specified markings. Any equipment judged to be unsuitable by the Engineer shall be repaired or replaced.

(D) Pavement Surface:

The contractor shall remove all dirt, dust, grease, oil, loose surfacing materials, poorly adhered existing markings, or other detrimental material from the road surface prior to application of the thermoplastic material.

The method of cleaning the surface is subject to approval by the Engineer and shall include sweeping and the use of high-pressure air spray. The method of surface preparation shall also be in accordance with the recommendations of the thermoplastic material manufacturer. Loose material including all grindings and obliterated markings shall be removed from the pavement surface and disposed of properly.

When thermoplastic markings are to be applied to new Portland cement concrete pavement, any curing compound present shall be removed by means of a high-pressure water jet or sandblasting, followed by sweeping and high-pressure air spray. The curing compound shall be removed at least two inches beyond the entire perimeter of each marking to be installed.

At the time of application of primer-sealer and thermoplastics, the road surface shall be absolutely dry with no detectable or measurable surface or near-surface dampness. If precipitation or other surface wetting is imminent, all marking operations shall be stopped. If any surface dampness is detected during marking activities, marking operations shall be stopped until the pavement dries. If the hot-applied thermoplastic marking blisters upon application, marking operations shall be stopped until the cause, potentially including subsurface moisture, is determined and corrected.

(E) Primer Application:

On both old and new Portland cement concrete pavement, a primer-sealer shall be used if recommended by the thermoplastic manufacturer. The primer-sealer shall be applied at the manufacturer's recommended application rates prior to placing the thermoplastic material. The primer-sealer shall be allowed to set up for the manufacturer's specified cure or evaporation time, and shall be free of solvent and water when the thermoplastic is applied.

The thermoplastic material shall be applied to primed pavement surfaces within the working time specified by the primer-sealer and thermoplastic materials manufacturers. If the primed surfaces are not marked within these time limits, the contractor shall re-prime the surfaces as required by the manufacturer at no additional cost to the Department. If an epoxy primer is used, the thermoplastic application shall be completed before the epoxy has cured.

Improper primer-sealer application may result in bond failure between the thermoplastic and the pavement surface and may cause the thermoplastic surface to pinhole or blister. Should these conditions occur, all application operations shall stop until the cause is determined and corrected. All such defective markings shall be removed and replaced at no additional cost to the Department.

(F) Pavement Temperatures:

Ribbon-gun application procedures shall not be used if the wind chill factor is below 65 degrees F.

For other application procedures, the road surface temperature at the time of application shall be a minimum of 55 degrees F and rising.

If at any time during marking operations the air or pavement temperature falls below these requirements, all marking operations shall stop.

The contractor shall measure pavement surface temperatures one half hour prior to the start of the striping installation activities and as deemed necessary by the Engineer until the

end of the application period. For elevation changes greater than 1,000 feet, temperature readings at the highest elevation shall govern unless otherwise directed by the Engineer. The lowest temperature so measured shall govern, unless otherwise directed by the Engineer. The temperature measurements shall be recorded in a log book and provided to the Engineer when required. The pavement surface temperature shall be measured with a standard surface temperature thermometer or a non-contact infrared thermometer.

(G) Thermoplastic Application:

The thermoplastic pavement marking material shall be extruded or sprayed on to the pavement surface at a material temperature between 400 and 440 degrees , depending on manufacturer's recommendations, ambient air and pavement temperatures, and the nature of the pavement surface. The contractor shall verify temperature requirements with a non-contact infrared thermometer as directed by the Engineer.

The alkyd and hydrocarbon thermoplastic material temperatures shall not exceed 450 degrees F. Material temperatures exceeding 440 degrees F shall be allowed for short periods of time; however, in no case shall the material be held for more than four hours at temperatures above 440 degrees F. Total heating time for any batch of material shall not exceed six hours. The contractor shall note in the temperature log the time when each batch of thermoplastic material is first heated. The start of heating time shall also be marked on the side of the kettle to which it applies.

Specified temperature requirements shall be maintained at all times during application. The contractor shall monitor material temperature at thirty minute intervals, unless otherwise directed by the Engineer, and maintain a log of temperature readings taken. Readings shall be taken at the melting kettle or the application outlet point, as determined by the Engineer.

The contractor shall minimize the thermoplastic material remaining in the kettle at the end of the work day and shall blend a minimum of 80 percent fresh material the start of each day. During project delays, the contractor may transfer heated thermoplastic material into approved containers for later re-use, subject to specified limits on total acceptable heating time for each batch.

Drop-on glass beads shall be mechanically deposited, at the specified rate, into the thermoplastic material immediately after the thermoplastic marking is applied. The bead dispenser shall evenly distribute the beads such that they embed in the surface of the thermoplastic to a depth of between 50 and 60 percent of the bead diameter. If the glass beads do not adhere to the thermoplastic marking, operations shall be stopped until the problem has been corrected. All markings which do not meet the requirements of Subsection 704-2.03(C), as determined by the Engineer, shall be removed by the contractor and replaced at no additional cost to the Department.

Unless otherwise specified, thermoplastic pavement markings for legends and symbols, and for crosswalks, stop bars and other transverse elements, shall be extruded, and shall be 0.090 ± 0.002 inches thick. Longitudinal markings, such as edge lines, lane lines, gore lines, and other markings parallel to traffic, shall be sprayed thermoplastic, and shall be 0.060 ± 0.002 inches thick. Longitudinal markings of approximately 200 feet or less may be

extruded, and shall be a minimum of 0.060 ± 0.002 inches thick. The thermoplastic thickness shall be uniform and consistent throughout the total length of the marking project.

The contractor shall perform periodic spot checks of thermoplastic material to verify that the required thickness has been attained. Random spot checks of the thermoplastic thickness will be made by the Engineer to ensure conformance with the required criteria. Suggested spot check procedures include the following:

- Wet: Thickness can be field tested immediately after the thermoplastic marking is applied by inserting a thin, graduated machinist rule or similar instrument into the molten thermoplastic to the depth of the pavement surface. The thickness is then determined visually by noting on the scale the depth of the penetration or coating of the instrument.
- Dried: Thickness can be field tested by placing a small flat sheet of metal with a known thickness immediately ahead of the striping apparatus. After striping, remove the sample and use a suitable measuring device, such as a caliper or micrometer, to determine the thickness of the dried marking.

The finished thermoplastic line shall have well defined edges and be free from waviness. Lateral deviation of the thermoplastic line shall not exceed one inch in 100. The longitudinal deviation of a painted segment and gap shall not vary more than six inches in a 40-foot cycle. The actual width of line shall be within the limits specified in the following table, according to the width of line called for on the plans:

Plan Width	Actual Width
4 inches	4 to 4-1/2 inches
8 inches	8 to 9 inches
Over 8 inches	± 1 inch

After application and sufficient drying time, the thermoplastic marking shall show no appreciable deformation or discoloration under local traffic conditions with air and road temperatures ranging from -10 to 180 degrees F. The drying time shall be defined as the minimum elapsed time, after application, when the thermoplastic pavement markings shall have and retain the characteristics required herein, and after which normal traffic will leave no impression or imprint on the newly applied marking. When applied within a temperature range of 412.5 ± 12.5 degrees F and thickness range of 0.060 to 0.090 inches, the material shall set to bear traffic in not more than two minutes when the air and pavement surface temperatures are approximately $50 \pm$ three degrees F and not more than 10 minutes when the air and road surface temperatures are approximately $90 \pm$ three degrees. The Engineer may conduct field tests in accordance with ASTM D 711 to verify actual drying times.

704-4 Method of Measurement:

Thermoplastic pavement longitudinal and transverse markings, such as edge lines, lane lines, gore lines, cross-walks and stop bars, will be measured by the linear foot along the center line of the pavement marking line and will be based on a four-inch-wide line.

Measurement for striping with a plan width greater or less than the basic four inches as shown on the plans or directed by the Engineer will be made by the same method and then adjusted by the following factor:

$$\frac{\text{Plan Width of Striping (inches)} \times \text{Linear Feet}}{4 \text{ (inches)}}$$

No measurement will be made of the number of linear feet of gaps in dashed lines.

Double marking lines, consisting of two four-inch-wide stripes, will be measured as two individual marking lines. Crosswalk lines, stop bars, stop lines, gore lines, cross hatch lines, chevron lines and railroad marking transverse lines will be measured for centerline length and adjusted for widths other than four inches, as defined above.

Thermoplastic pavement marking symbols, such as diamonds, or single, double, or triple arrows, will be measured by each unit applied. Each pavement symbol, as shown on the plans, will be considered a unit.

Thermoplastic pavement marking legends, defined as a complete letter grouping such as "SCHOOL," "XING," "STOP," "RR," or "ONLY.", will be measured by each unit applied. Each pavement legend, as shown on the plans, will be considered a unit.

No separate measurement or payment will be made for cleaning and preparing the pavement surface, including abrasive sweeping and high-pressure air spray, and for disposal of excess materials, cleaning fluids, and empty material containers, the cost being considered as included in contract items.

Removal of curing compound from new Portland cement concrete pavement and the application of primer-sealer, which is to be applied to both old and new Portland cement concrete pavement prior to application of thermoplastic marking, shall be measured by the linear foot for striping lines regardless of width, or unit each for symbols and legends, and in accordance with the items of work established in the bid schedule.

704-5 Basis of Payment:

The accepted quantities of thermoplastic pavement markings of the type specified in the bidding schedule, measured as provided above, will be paid for at the contract unit price, complete in place, including pavement surface preparation and glass beads.

The accepted quantities for removal of curing compound from new Portland cement concrete pavement and the application of primer-sealer, measured as provided above, will be paid for at the respective contract unit prices, under the items of work established in the bid schedule.

SECTION 705 PREFORMED PLASTIC PAVEMENT MARKING:

705-1 Description:

The work under this section shall consist of furnishing all materials, preparing the pavement surface and applying preformed reflectorized pavement marking tape, arrows and legends to the pavement in accordance with the details shown on the project plans and the requirements of these specifications.

Preformed pavement marking tape, arrows and legends shall be limited to the following applications unless otherwise specified in the contract documents:

(A) Preformed Pavement Markings - Type I (Permanent):

Type I shall be a general purpose high durability retroreflective pliant polymer film for preformed striping and markings to be used for finished permanent markings. Type I shall be capable of performing as specified herein when subjected to high traffic volumes and severe wear conditions such as repeated shear action from crossover or encroachment on edge and channelization lines, starting, stopping, and turning movements.

(B) Preformed Pavement Markings - Type II (Temporary - Removable):

Type II shall be a removable preformed retroreflective pavement marking capable of performing for the duration of a normal construction season. It shall be a nonmetallic mixture of high quality materials and shall be capable of being removed intact or in large pieces either manually or with a recommended roll up device. Type II shall be used on finished pavement surfaces where traffic control or channelization through the construction zone is temporary requiring removal prior to final pavement markings.

(C) Preformed Pavement Markings - Type III (Temporary - Nonremovable):

Type III shall be a nonremovable preformed retroreflective film on a conformable metallic backing capable of performing for the duration of a normal construction season. Type III shall be used in construction zones where removal is unnecessary due to placement of future paving courses or where pavement will be removed, obliterated or abandoned at the completion of the project.

705-2 Materials:

705-2.01 Preformed Pavement Markings - Type I (Permanent):

(A) General:

Certificates of Compliance conforming to the requirements of Subsection 106.05 shall be submitted.

Type I preformed plastic pavement marking material shall consist of a homogeneous, extruded, pre-fabricated white or yellow thermoplastic film of specified thickness and width that shall be capable of being affixed to nonbleeding bituminous or Portland cement concrete. It shall contain reflective glass beads uniformly distributed throughout the entire

cross section and bonded to the top surface of the material. The preformed plastic film shall be weather resistant and through normal traffic wear shall show no appreciable fading, lifting, or shrinkage or significant tearing, roll back, or other signs of poor adhesion throughout the useful life of the marking.

When extruded, the plastic film without adhesive shall be a minimum of 0.060 inch thick. The plastic film as supplied shall be of good appearance, free of cracks and discolorations, and the edges shall be clean-cut and well defined. The plastic film may be supplied complete with a precoated, factory-applied pressure sensitive adhesive backing with a protective release paper, or it may be furnished with separate adhesive as recommended by the manufacturer. Whether the adhesive is precoated or supplied separately, the adhesive shall be such as to allow the plastic film to be repositioned on the pavement surface to which it is applied before permanently fixing it in its final position with a downward pressure.

A list of approved manufacturers and distributors for Type I (permanent) preformed pavement marking material are shown on the Department's Approved Products List (APL). Copies of the most recent version of the APL are available on the internet at <http://www.dot.state.az.us/ABOUT/atrc/apl.htm>.

(B) Composition Requirements:

The preformed plastic pavement marking material shall consist of the following components:

Minimum Percent by Weight	
Resins and Plasticizers	20
Pigments	30
Reflective Glass Beads	20

(C) Physical Requirements:

(1) Color:

The pigments shall be selected and blended to provide a white or yellow marking film which conforms to standard highway colors throughout the expected life of the film.

(2) Bend Test:

The plastic film shall be sufficiently flexible so that at a temperature of 78 to 82 degrees F an unmounted piece of material (without adhesive and paper backing), three by six inches in size, may be bent over a one-inch mandrel until the end faces are parallel and one inch apart without showing any fracture lines in the uppermost surface.

(3) Tensile Strength:

The plastic film (without adhesive or paper backing) shall have a minimum tensile strength of 40 pounds per square inch when a specimen six inches long by one inch wide is tested in

accordance with the requirements of ASTM D 638. The rate of pull of the test shall be 0.25 of an inch per minute. The test shall be conducted at a temperature between 70 and 80 degrees F. The elongation shall be no greater than 75 percent.

(4) Plastic Pull Test:

A six-inch long by one-inch wide section of the plastic film (without adhesive and paper backing) shall support a dead load weight of four pounds for not less than five minutes at a temperature between 70 and 80 degrees F.

(5) Abrasion Resistance:

The plastic film shall have a maximum loss in weight of 0.25 grams in 500 revolutions when abraded according to Federal Test Method Standard No. 141, Method 6192, using H-18 calibrase wheels with a 1000-gram load on each wheel.

**705-2.02 Preformed Pavement Markings - Type II
(Temporary - Removable):**

Certificates of Compliance conforming to the requirements of Subsection 106.05 shall be submitted.

Type II preformed pavement markings shall be a non-metallic mixture of conformable materials and pigments intended for marking applications where removability is required. The marking material shall be white or yellow retroreflective film conforming to standard highway colors with glass beads in a reflective layer bonded to the top surface. The glass beads shall meet the durability and reflectance criteria specified in Subsection 705-2.04.

The markings shall be precoated with a pressure sensitive adhesive capable of adhering to roadway surfaces under climatic and traffic conditions normally encountered in the construction work zone when applied in accordance with the manufacturer's instructions and without the use of heat, solvents or other additional adhesives. Newly applied markings shall be capable of being immediately exposed to traffic without pickup or distortion by vehicles. The markings shall be weather resistant and through normal traffic wear shall show no appreciable fading, lifting, shrinkage, tearing, roll back or other signs of poor adhesion throughout the useful life of the marking.

Temporary pavement markings shall be removable from asphalt and concrete pavement intact or in large sections by following the manufacturer's instructions. It shall be removable either manually or with a roll-up device at pavement temperatures above 40 degrees F without the use of heat, solvents, grinding or sand blasting. Visible adhesive residue remaining after removal of temporary pavement markings shall be easily removable without damaging or scarring the pavement surface and without the use of solvents or grinding.

When extruded, pavement marking material without adhesive shall be a minimum of 0.045 inches thick. When supplied, the material shall be of good appearance, free from cracks, and edges shall be true, straight, and unbroken.

**705-2.03 Preformed Pavement Markings - Type III
(Temporary - Nonremovable):**

Certificates of Compliance conforming to the requirements of Subsection 106.05 shall be submitted.

Type III preformed pavement markings shall be a retroreflective film on a conformable metallic backing intended for marking applications where removal is not a requirement. The marking material shall be white or yellow conforming to standard highway colors and shall contain glass beads meeting the durability and reflectance criteria specified in Subsection 705-2.04.

The markings shall be precoated with a pressure sensitive adhesive capable of adhering to roadway surfaces under climatic and traffic conditions normally encountered in the construction work zone when applied in accordance with the manufacturer's instructions and without the use of heat, solvents or other additional adhesives. Newly applied markings shall be capable of being immediately exposed to traffic without pickup or distortion by vehicles. The markings shall be weather resistant and through normal traffic wear shall show no appreciable fading, lifting, shrinkage, tearing, roll back or other signs of poor adhesion throughout the useful life of the marking.

705-2.04 Reflective Glass Beads:

(A) General Requirements:

The beads shall be manufactured from glass of a composition designed to be highly resistant to traffic wear and to the effects of weathering.

During manufacture of the preformed plastic pavement marking material, reflective glass beads shall be mixed into the material in the amounts indicated. A layer of reflective glass beads shall be bonded to the top surface of all types of preformed pavement marking materials.

(B) Physical Requirements:

(1) Roundness:

The roundness of the glass beads shall be determined in accordance with the requirements of ASTM D 1155. A minimum of 75 percent of the beads shall be water-white true spheres free from imperfections of all types including air inclusions, film, scratches, clusters, and surface scoring.

(2) Index of Reflection:

The glass beads used with the preformed pavement marking material shall have a reflective index of not less than 1.50 when tested by the liquid immersion method at 25 °C.

(3) Gradation:

The size of the glass beads shall be such that performance requirements for the preformed pavement marking material shall be met.

(4) Chemical Resistance:

The glass beads shall withstand immersion in water and acids without undergoing noticeable corrosion or etching and shall not be darkened nor otherwise noticeably decomposed by sulfides. The test for chemical resistance shall consist of placing three- to five-gram portions of the sample in each of three pyrex glass beakers or porcelain dishes; one sample shall be covered with distilled water, one with a 3N solution of sulfuric acid and the other with a 50 percent solution of sodium sulfide. After one hour of immersion, the glass beads of each sample shall be examined microscopically for evidence of darkening and frosting.

705-3 Construction Requirements:

The contractor shall install preformed pavement markings at the locations shown on the project plans, as specified in the Special Provisions, or as directed by the Engineer. Preformed marking tape shall be applied manually or with the tape applicators approved by the tape manufacturer. All markings shall be applied in accordance with the manufacturer's recommendations and as specified herein. Preformed pavement markings shall not be applied over other markings or old paint unless specified in the project plans or directed by the Engineer.

Preformed pavement markings shall be applied to surfaces that are free of moisture and thoroughly cleaned of loose, foreign or other material that may adversely affect bonding. The contractor shall remove all dirt, dust, grease, oil or other detrimental material from the road surface. The method of cleaning the surface is subject to approval by the Engineer and shall include sweeping and the use of high-pressure air spray. Newly placed surfaces need not be cleaned unless, in the opinion of the Engineer, the surface has become contaminated to the extent that cleaning is necessary to provide proper bonding. Preformed pavement markings shall be applied immediately after the surface has been prepared or as soon as possible after placement and completion of new pavement. At the time of application, the road surface temperature shall not be less than 60 degrees F and the pavement surface shall be absolutely dry. For temporary markings, the weather conditions noted above may be waived, at the Engineer's discretion, to obtain a traffic stripe prior to allowing traffic to traverse the roadway. Despite the required minimum surface temperature and surface condition, the Engineer, at any time, may require that work cease or that the work day be reduced in the event of weather conditions, either existing or expected, which would have an adverse affect upon the working conditions.

The contractor shall use butt splices only and shall not overlap the marking material. All markings shall be thoroughly tamped with approved mechanical tampers.

The contractor shall immediately correct all misalignments when so ordered by the Engineer. The misaligned portions shall be removed and reinstalled in accordance with

these specifications. All areas marked with preformed marking tape shall be ready for traffic immediately after application.

Temporary pavement markings shall be maintained and replaced when necessary by the contractor until they are covered with the next overlay course or are removed because they are no longer applicable. The temporary pavement markings shall be removed immediately, when no longer needed for traffic control or when the temporary pavement markings will be in conflict with the succeeding traffic pattern. This removal includes the removal of pronounced markings caused by the adhesive across lanes, transitions or tapers. Removable temporary marking material shall not be burned or ground off. Preformed pavement markings shall be removed by methods recommended by the manufacturer and approved by the Engineer. Residual adhesive, ghosting, shadows or pavement scarring which might cause confusion during darkness or adverse weather conditions shall be removed immediately by the contractor when so ordered by the Engineer.

The application of preformed pavement markings shall be in accordance with the recommendations of the manufacturer of the material and these specifications; however, minor changes will be allowed if such are shown to produce an equal or better application and is approved by the Engineer. Failure to satisfactorily adhere to the pavement or to be satisfactorily removable shall be reason for disallowing the use of any particular type of marking material. Approval for use of any type of marking material is subject to satisfactory performance under traffic. Any failure during the time frame the material is scheduled to perform shall be repaired immediately by the contractor. Continued failure of a material to perform shall be cause for disallowing further use of that particular manufacturer's material.

Failure of materials, inadequate marking characteristics, or any other confusing or unsafe condition in a construction work zone will not be tolerated. Any condition where the safety of workmen or the traveling public might be endangered shall be remedied immediately by the contractor if so ordered by the Engineer.

705-4 Method of Measurement:

Measurement of preformed pavement marking arrows and legends will be made for each arrow or legend, as shown on the plans, furnished and applied in accordance with the requirements specified herein and on the plans.

Measurement of preformed pavement marking lines will be made by the linear foot along the center line of the pavement line and will be based on a four-inch wide stripe. Measurement for pavement lines with a plan width greater or less than the basic four inches will be made by the following method:

$$\frac{\text{Plan Width of Striping (inches)} \times \text{Linear Feet}}{4 \text{ (inches)}}$$

When Type II or III temporary preformed pavement markings are required for maintaining traffic through a construction work zone and are approved for use by the Engineer, but are

not listed as pay items in the bidding schedule, they will be paid for in accordance with the provisions of Subsection 109.04.

705-5 Basis of Payment:

The accepted quantities of preformed pavement markings, measured as provided above, will be paid for at the contract unit price for the type specified in the bidding schedule, which price shall be full compensation for the item, complete in place, including necessary pavement cleaning, removal of Type II temporary markings, and maintaining Types II and III temporary markings in construction work zones.

When Type II or III temporary preformed pavement markings are required for maintaining traffic through a construction work zone, but are not listed as pay items in the bidding schedule, they will be considered as included in the lump sum paid for Maintenance and Protection of Traffic in accordance with Subsection 701-5.

Additional payment will be made for replacement of temporary markings when the contractor is required by the Engineer to install marking materials on distressed pavements or during adverse weather conditions and subsequent failure occurs. Distressed pavement conditions are defined as alligator cracking, bleeding, or spalling of bituminous pavements and spalling of PCC pavements. Adverse weather conditions are defined as any occurrence where application is required at pavement temperatures less than 60 degrees F or when precipitation occurs within 24 hours before or after application. The Department will pay for the replacement, where failures occur, at the contract unit price for the initial occurrence.

In the event a second failure occurs when markings have been reapplied on distressed pavements or under weather conditions described above, the Engineer shall determine if conditions require primer, alternate methods of marking, or reapplication of preformed markings. Preformed markings will be paid for at the contract unit price. Primers or other methods of markings deemed necessary by the Engineer will be paid for in accordance with the provisions of Subsection 109.04.

SECTION 706 RAISED PAVEMENT MARKERS:

706-1 Description:

The work under this section shall consist of cleaning and preparing the pavement surface; furnishing all materials, equipment, tools and labor; and placing raised pavement markers of the type specified at the locations and in accordance with the details shown on the plans and the requirements of these specifications.

706-2 Materials:

706-2.01 General:

Certificates of Compliance, for raised pavement markers and adhesive, conforming to the requirements of Subsection 106.05 shall be submitted to the Engineer at least 10 days prior to use. A minimum of one sample per lot per type of marker shall be taken by the Engineer.

The pavement marker samples shall be tested to determine conformance to the applicable standard drawings and these specifications.

The base of the pavement markers shall be free from glass glaze or from substances which may reduce its bond to the adhesive. The base shall be flat and its deviation from a flat surface shall not exceed 0.05 inches.

706-2.02 Reflective Pavement Markers:

Reflective pavement markers shall be of the following type:

Type C	Clear, red
Type D	Yellow, two-way
Type E	Clear, yellow
Type G	Clear, one-way
Type H	Yellow, one-way

Reflective pavement markers shall be of the prismatic reflector type consisting of a molded methyl methacrylate or suitably compounded acrylonitrile butadiene styrene (ABS) shell filled with a mixture of an inert thermosetting compound and filler material. The exterior surface of the shell shall be smooth and shall contain one or two prismatic reflector faces of the color specified.

When illuminated by an automobile headlight, the color of the reflectors shall be an approved clear, yellow, or red as designated. Reflectors not meeting the required color may be rejected.

Permanent reflective pavement markers will be tested for compressive strength, abrasion resistance and specific intensity. Permanent reflective pavement markers shall have thin untempered glass or other abrasion resistant material bonded to the prismatic reflector face to provide an extremely hard and durable, abrasive resistant reflector surface.

The glass, or other abrasion resistant surface, is not required on the red faces of two-way (Clear/Red) permanent reflective markers. The area covered by the glass, or other abrasion resistant surface, shall not be less than three square inches.

Temporary reflective pavement markers will be tested for compressive strength and specific intensity. Temporary reflective pavement markers, or permanent reflective pavement markers used as temporary, will not be tested for abrasion resistance.

The strength by compressive loading shall be at least 2,000 pounds for both permanent and temporary reflective pavement markers.

The original specific intensity of each reflecting surface for both temporary and permanent reflective markers shall not be less than the following:

Reflectance: degrees incidence	Specific Intensity: candelas/foot-candle		
	Clear	Yellow	Red
0	3.0	1.8	0.75
20	1.2	0.72	0.30

Permanent reflective pavement markers shall be subject to an abrasion resistance test as follows:

Steel Wool Abrasion Procedure: Form a one-inch diameter flat pad using No. 3 coarse steel wool per Federal Specification FF-W1825. Place the steel wool pad on the reflector lens face. Apply a force of 50 pounds and rub the entire lens surface 100 times. After the lens surface has been abraded, the specific intensity of each clear and yellow reflective surface shall be not less than that required above for the original specific intensity.

706-2.03 Non-Reflective Pavement Markers and Reflectorized Dagmars:

Non-reflective pavement markers shall be of the following types:

Type	Color
A	white
AY	yellow

Reflectorized Dagmars shall be of the following types:

Type J	white
Type JY	yellow

Non-reflective pavement markers and reflectorized dagmars shall consist of a heat-fired, vitreous ceramic base and a heat-fired, opaque glazed surface which will produce the required properties. Markers shall be produced from any suitable combination of intimately mixed clays, shales, flints, feldspars, or other inorganic material which will meet the properties herein required. Markers shall be thoroughly and evenly matured and free from defects which will affect appearance or serviceability.

The top surface of the marker shall be in reasonably close conformity with the configuration shown on the plans. Markers shall be convex and the radius of curvature shall be between 3-1/2 and six inches, except that the radius of the 1/2 inch nearest the edge may be less. All edges shall be rounded and any change in curvature shall be gradual. The top and sides shall be smooth and free of mold marks, pits, indentations, air bubbles, or other objectionable marks or discolorations.

Non-reflective pavement markers and dagmars shall meet the following requirements:

Glaze Thickness: Inches	0.005 Minimum
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Moh Hardness:	6 Minimum
Directional Reflectance: (White Only) Glazed Surface Body of Marker	75 Minimum 70 Minimum
Yellowness Index: (White Only) Glazed Surface Body of Marker	0.07 Maximum 0.12 Maximum
Color (Yellow Only): Purity: percent, range Dominant Wave Length: mu, range Total Luminous Reflectance (Y valve)	75 - 96 579 - 585 0.41 Minimum
Compressive Strength: pounds	1,500 Minimum
Water Absorption: percent	2.0 Maximum
Autoclave	Glaze shall not spall, craze or peel

Reflectorized dagmars shall have encapsulated lens reflectors conforming to standard manufacturing practices.

706-2.04 Jiggle Bars:

(A) General:

Types K and KY jiggle bars shall be concrete or ceramic, at the option of the contractor, and shall be shaped to conform to the details shown on the plans. The same type of jiggle bar shall be used throughout any one project.

Jiggle bars shall be painted either white or yellow and shall be reflectorized, as shown on the plans. The color shall be uniform.

The bottom surface of the jiggle bars shall be of a roughness comparable to at least that of fine grade sandpaper. The bottom surface shall not be grooved such that air will be trapped in the grooves when it is pressed into the adhesive.

(B) Concrete:

Concrete jiggle bars shall be made of Class B concrete conforming to the requirements of Section 1006.

(C) Ceramic:

Ceramic jiggle bars shall be made of a heat-fired vitreous base. The glazed surface shall not craze, spall or peel when tested in accordance with the requirements of ASTM C 424 for one cycle at 250 pounds per square inch.

The jiggle bar tiles shall have a compressive strength as follows when tested in accordance with the requirements of ASTM C 773:

Minimum average of five units	6,000 psi
Individual minimum, one unit	5,000 psi

706-2.05 Bituminous Adhesive:

The bituminous adhesive for pavement markers shall be a hot-melt adhesive manufactured by an approved manufacturer. A list of approved manufacturers of bituminous adhesive is shown on the Department's Approved Products List (APL). Copies of the most current version of the APL are available on the internet at <http://www.dot.state.az.us/ABOUT/atrc/apl.htm>.

706-3 Construction Requirements:

The portion of the highway to which the markers are to be attached shall be free of dirt, existing painted lines, curing compound, grease, oil, moisture, loose or unsound layers and any other material which could adversely affect the bond of the adhesive. The method of cleaning the pavement surface and removal of detrimental material is subject to approval by the Engineer and shall include sweeping and the use of high-pressure air spray. On Portland cement concrete pavement and old asphaltic concrete pavements, cleaning shall be accomplished by sandblasting, followed by sweeping and/or air blowing. Newly placed asphaltic concrete pavement need not be sandblasted unless, in the opinion of the Engineer, the surface is contaminated with materials that would adversely affect the bond of the adhesive.

The adhesive shall be placed uniformly on the cleaned pavement surface in an amount sufficient to result in complete coverage of the area of contact of the markers, with no voids present and with a slight excess after the markers have been placed. The markers shall be placed in position and pressure applied until firm contact is made with the pavement. The markers shall be protected against impact until the adhesive has set to the degree acceptable to the Engineer.

Excess adhesive on the pavement and on the exposed surfaces of the markers shall be immediately removed. Thinners or solvents which may be detrimental to either the markers or the bond provided by the adhesive shall not be used in removing excess adhesive.

Markers shall not be installed when the temperature of the pavement surface or the atmosphere is less than 40 degrees F, when the relative humidity is 80 percent or higher or when the pavement surface is not dry.

All markers shall be installed to the line approved by the Engineer and in such manner that the reflective face of the markers is perpendicular to a line parallel to the roadway centerline. No pavement markers shall be installed over longitudinal or transverse joints of the pavement surface.

706-4 Method of Measurement:

Pavement markers will be measured as a unit for each marker furnished and placed.

706-5 Basis of Payment:

The accepted quantities of pavement markers, measured as provided above, will be paid for at the contract unit price for the type designated in the bidding schedule, complete in place, including adhesive and surface preparation.

SECTION 707 TUBULAR MARKER (Flexible):

707-1 Description:

The work under this section shall consist of furnishing and installing flexible tubular markers in accordance with the details shown on the project plans and the requirements of these specifications. The work shall also include the removal and salvage of the markers when ordered by the Engineer.

707-2 Materials:

The post shall be of a flexible material which is resistant to impact, ultra violet light, ozone, hydrocarbons and stiffening with age. The base shall prevent post removal by impact or vandals. The post and base shall exhibit good workmanship and shall be free of burns, discoloration, contamination, and other objectionable marks or defects which affect appearance or serviceability.

The post shall be designed to resist overturning, twisting and displacement from wind and impact forces. A 50-mile per hour wind load shall not deflect the post more than two inches from the at-rest position. Measurement shall be made at the point of maximum deflection and normal to the movement.

The post shall have minimum tensile strength of 1,100 pounds per square. The tensile stress shall be determined in accordance with the "Standard Method of Test for Tensile Properties of Plastic," ASTM D 638 (Test Specimen Type 1). The rate of jaw separation shall be 20 inches per minute.

The post shall be conditioned for a minimum of two hours in an oven at $140 \pm$ three degrees F. The conditioned post shall be capable of straightening itself within 30 seconds when bent 180 degrees at the midpoint for each of four bends. The stress test on each post shall be completed within two minutes of removal from oven.

The post shall be sufficiently rigid to resist wilting after conditioning a minimum of two hours at $180 \pm$ three degrees F.

The post shall be conditioned a minimum of two hours at $-5 \pm$ three degrees F in an environmentally controlled test chamber. Testing shall be performed in the environmental chamber. The post shall be sufficiently flexible to permit four 180-degree bends at the midpoint without cracking, each time straightening itself within 60 seconds.

The post shall be manufactured from an impact resistant material so that an installed post is capable of self-erecting and withstanding 10 vehicle impacts at 55 miles per hour at temperatures of 40 degrees F or above without breakage or loss of serviceability. Little or no damage shall be caused to the impacting vehicle. The vehicle shall be a typical sedan with a weight of $4,000 \pm 1,000$ pounds.

The post shall also be capable of sustaining a wheel hit during testing at 55 miles per hour without loss of serviceability.

The reflective sheeting shall be a high reflectivity flexible sheeting conforming to the requirements of Section 1007. The sheeting must retain 75 percent of its reflectivity after 10 vehicle impacts at 55 miles per hour. Color shall be silver-white, yellow, or green in accordance with the appropriate Federal Highway Administration color tolerance chart.

The base shall prevent post removal by impact or vandals. The base shall not protrude more than four inches above the pavement surface.

707-3 Construction:

The base shall be installed with an epoxy adhesive or acceptable alternate, in accordance with the manufacturer's specifications.

When used in a construction work zone, it shall be the contractor's responsibility to keep the tubular markers bright and clean for maximum target value.

When replacement, repair or resetting of markers is necessary during traffic control in a construction work zone, such work shall be done immediately by the contractor.

707-4 Method of Measurement:

Tubular markers will be measured by the unit for each marker furnished and installed.

707-5 Basis of Payment:

The accepted quantities of tubular markers, measured as provided above, will be paid for at the contract unit price each, which price shall be full compensation for the work, complete in place, as specified herein and as shown on the plans.

It shall be the contractor's responsibility to reset those markers that become detached from the pavement at no additional cost to the Department.

Where the Engineer determines markers are in need of repair, such repairs shall be made by the contractor and will be paid for in accordance with the provisions of Subsection 109.04.

Where the Engineer determines markers need to be replaced, such replacement shall be made by the contractor and additional payment will be made at the contract unit price.

No measurement or direct payment will be made for removing, hauling and stockpiling salvaged markers, the cost being considered as included in the cost of the contract item.

SECTION 708 PERMANENT PAVEMENT MARKINGS:

708-1 Description:

The work under this section shall consist of cleaning and preparing the pavement surface, furnishing all materials and applying white or yellow, water-borne, lead-free, rapid-dry traffic paint and reflective glass beads at the locations and in accordance with the details shown on the plans, MUTCD, and associated ADOT Supplement, the requirements of these specifications, or as directed by the Engineer.

708-2 Materials:

708-2.01 Pavement Marking Paint:

(A) General:

All material used in the formulation of the pavement marking paint shall meet the requirements herein specified. Any materials not specifically covered shall meet the approval of the Engineer.

Certificates of Compliance conforming to the requirements of Subsection 106.05 shall be submitted for each lot or batch of paint prior to its use.

(B) Composition Requirements:

The pavement marking paint shall be a ready-mixed, one component, water-borne lead-free traffic line paint, of the correct color, to be applied to either asphaltic or Portland cement concrete pavement. The composition of the paint shall be determined by the manufacturer. It will be the manufacturer's responsibility to produce a pigmented water-borne paint containing all the necessary co-solvents, dispersant, wetting agents, preservatives and all other additives, so that the paint shall retain its viscosity, stability and all of the properties as specified herein. The manufacturer shall certify that the product does not contain mercury, lead, hexavalent chromium, toluene, chlorinated solvents, hydrolyzable chlorine derivatives, ethylene-based glycol ethers and their acetates, and not any carcinogen, as defined in 29 CFR 1910.1200. Lead content shall not exceed 0.06 percent of weight of the dry film, and the test for chromium content shall be negative.

No glass beads will be allowed in the pavement marking paint. Glass beads will be applied after the paint has been applied.

(C) Manufacturing Formulations:

The manufacturer shall formulate the pavement marking paint in a consistent manner and notify the Engineer of any change of formulation. The formulation of the paint shall be

determined by the manufacturer. It will be the manufacturer's responsibility to formulate paint which will meet the quantitative and qualitative requirements of this specification. Any change in the formulation of the paint must be approved by the Engineer.

(D) Quantitative Requirements of Mixed Paints:

	White	Yellow
Pigment:		
Percent by weight, ASTM D 3723, allowable variation from qualifying sample	± 2.0	± 2.0
Non-Volatile Content:		
Percent by weight, ASTM D 2369, allowable variation from qualifying sample	± 2.0	± 2.0
Viscosity: Krebs Units at 77 ± 1 °F, ASTM D 562	70 - 85	70 - 85
Weight per Gallon:		
pounds per gallon 77 ± 1 °F, ASTM D 1475P, allowable variation from qualifying sample	± 0.3	± 0.3
Vehicle Composition:		
Vehicle Infrared Spectra, ASTM D 2621, allowable variation from qualifying sample	None	None
PH: ASTM E 70, allowable variation from qualifying sample	± 1.0	± 1.0
Fineness of Dispersion:		
HEGMAN, minimum, ASTM D 1210	3.0	3.0
Volatile Organic Compounds:		
pounds per gallon of paint, maximum, ASTM D 3960 according to 7.1.2.	2.1	2.1
Flash Point:		
Degrees F., minimum, ASTM D 93, Method A	100	100
Dry Time to No Pick Up:		
with no beads: minutes, maximum, ASTM D 711	10	10
Dry Through Time:		
Minutes, ASTM D 1640 except no thumb pressure is used when thumb is rotated 90° on paint film	20	20
Flexibility: TT-P-1952D	Pass	Pass

(E) Qualitative Requirements:

(1) Color of Yellow Paint:

The color of the yellow paint shall closely match Federal Standard 595b, Color No. 33538. The color shall be checked visually, and will be checked against Tristimulus Values for the color according to Federal Test Method Standard No. 141.

(2) Dry Opacity:

Dry opacity for the paint will be determined using a black-white Leneta Chart, Form 2C Opacity and a Photovolt 577 Reflectance Meter or equal. Using a 10-mil gap doctor blade, a film of paint is drawn down, covering both black and white portions of the chart. The film shall be allowed to dry 24 hours. After calibrating the Reflectance Meter according to the manufacturer's instructions, measure the reflectance over the white and black portions with the green Tristimulus filter. Dry Opacity is calculated as follows:

$$\text{Dry Opacity} = \frac{\text{Re flectance over black}}{\text{Re flectance over white}}$$

Dry Opacity for both white and yellow paint shall be a minimum 0.90.

(3) Yellowness Index:

Yellowness Index for white paint will be determined as described for dry opacity, only use a 15-mil gap doctor blade to draw down the paint. After 24 hours for drying, measure the reflectance of the paint film, using the green, blue, and amber Tristimulus filters. Calculate the Yellowness Index as follows:

$$\text{Yellowness Index} = \frac{\text{Amber} - \text{Blue}}{\text{Green}} \times 100$$

Yellowness Index for the white paint shall be a maximum of 10.

(4) Reflectance:

Reflectance for both white and yellow paint will be determined using the same 15-mil draw-down film as for the Yellowness Index. For white paint the same sample may be utilized for both the Yellowness Index and Reflectance. Measure the reflectance of the paint film using the green Tristimulus filter. Reflectance for the white paint shall be a minimum of 85. Reflectance for the yellow paint may range from 42 to 59, inclusive.

(5) UV Color Durability:

UV Color Durability shall be determined using a QUV Weatherometer, with Ultra Violet Light and Condensate Exposure according to ASTM G 53, for 300 hours total. The repeating cycle shall be four hours UV exposure at 60 °C followed by four hours condensate exposure at 40 °C. After 300 hours of exposure, the Yellowness Index for white paint shall not exceed 12, and yellow paint must still match Federal Standard 595b, Color No. 33538.

(6) Static Heat Stability:

To determine static heat stability for the paint, place one pint of paint in a sealed can and heat in an air circulation oven at 120 ± one degrees F for a period of one week. Remove the paint from the oven and check the viscosity in Krebs Units at 77 ± one degrees F according to ASTM D 562. The viscosity measured must be in the range from 68 to 90, inclusive. Also, check for any signs of instability.

(7) Heat-Shear Stability:

To determine heat-shear stability for the paint, one pint of the paint is sheared in a Waring Blender at high speed to 150 degrees F. The blender should have a tight fitting lid taped onto it to minimize volatile loss. When the paint reaches 150 degrees F, stop the blender, immediately pour the paint into a sample can, and apply a cover to seal the can. Let the paint cool overnight and examine for jelling or other signs of instability. Measure viscosity in Krebs Units at 77 ± one degrees F according to ASTM D 562. The viscosity measured must be in the range from 68 to 95 inclusive. If not within the upper limit, run total solids on the sheared paint and adjust solids, if necessary, by adding water to reach the original solids content. If the solids content required adjustment, again check the viscosity of the paint. The viscosity must be in the range from 68 to 95 inclusive.

(8) Scrub Resistance:

Scrub Resistance will be determined according to ASTM D 2486. Use an appropriate doctor blade to provide a dry film thickness of three to four mils. Allow the paint to cure for 24 hours. Perform the scrub resistance test at 77 ± one degrees F and 50 ± five percent humidity. Record the number of cycles to remove the paint film. The number of cycles recorded must be a minimum of 800.

(9) Spraying Properties:

The paint shall be applied at a 15 mils wet film thickness in the field. The paint shall show the following properties at ambient temperatures of 50 to 100 degrees F with a paint spray temperature of 150 degrees F, maximum, and six to eight pounds of post-applied glass beads per gallon of paint. Beads shall conform to subsection 708-2.02 of these specifications.

- (a) Dry to a no-track condition in five minutes or less when the line is crossed over in a passing maneuver with a standard-sized automobile.
- (b) Produce a clean-cut, smooth line with no overspray or puddling.

- (c) Paint immediately after application shall accept glass beads so that the spheres shall be embedded into the paint film to a depth of 50 percent of their diameter.
- (d) Paint when heated to the temperature necessary to obtain the specified dry time, shall show no evidence of instability such as viscosity increase, jelling, or poor spray application.

(10) Freeze-Thaw Properties:

The paint viscosity or consistency shall not change significantly when the paint is tested for resistance to five cycles of freeze-thaw according to ASTM D 2243.

(11) Road Service Rating:

Test stripes of the paint shall be applied transversely across the road, four inches in width and approximately 12 feet long at a location approved by the Engineer.

Wet film thickness of the test stripes shall be approximately 15 mils as determined according to ASTM D 4414 and ASTM D 713 prior to test stripe application. To aid in obtaining the correct film thickness, a length of roofing paper placed by the side of the road can be used. Place a rigid metal test panel on the roofing paper in the path of a test line. Immediately after the test line is applied by the striper, measure the wet film thickness. If not satisfactory, adjust the spray pressure and repeat until the target wet film thickness is attained. It is important that no glass beads be present that would give a false wet film thickness. When the wet film thickness is correct, apply a test line across a tared metal test panel. After this, apply another test line across a different tared metal test panel, this time also adding the beads. These samples are necessary to determine the initial bead retention.

Glass beads conforming to the requirements of Subsection 708-2.02 of these specifications (moisture proof type) will be applied after the paint has been applied, but during the same striping operation at a rate such that the initial bead retention on the test line is a minimum of six pounds of beads per gallon of wet paint. The initial bead retention will be determined analytically by the ADOT Materials Group concurrently with the determination of the dry paint thickness utilizing tared metal test panels. The paint shall accept the glass beads so that the spheres are embedded into the paint film to a depth of 50 percent of their diameter. Test stripes will be observed for a period of 180 days from date of application. Paints will be evaluated for wear according to ASTM D 913.

After 180 days of service, on a visual rating scale of 0 to 100 percent, paints must have a rating of 92 percent or better to be acceptable. All ratings will be taken in the wheel track area. Glass beads shall show no more than a 30 percent loss after 180 days of test. This will be determined by taking close-up photographs of the paint film and by count determining the average bead loss.

The road service test may be waived at the option of the Engineer or evaluated for a period of time less than 180 days.

(12) Workmanship:

Paint shall be free from foreign materials, such as dirt, sand, fibers from bags, or other material capable of clogging screens, valves, pumps, and other equipment used in a paint striping apparatus.

The paint pigment shall be well ground and properly dispersed in the vehicle. The pigment shall not cake or thicken in the container, and shall not become granular or curdled. Any settlement of pigment in the paint shall result in a thoroughly wetted, soft mass permitting the complete and easy vertical penetration of a paddle. Settled pigment shall be easily redispersed, with minimum resistance to the sidewise manual motion of a paddle across the bottom of the container, to form a smooth uniform product of the proper consistency. If the paint cannot be easily redispersed, due to excessive pigment settlement as described above or due to any other cause, the paint shall be considered unfit for use.

The paint shall retain all specified properties under normal storage conditions for 12 months after acceptance and delivery. The contractor shall be responsible for all costs and transportation charges incurred in replacing paint that is unfit for use. The properties of any replacement paint, as specified herein, shall remain satisfactory for eight months from the date of acceptance and delivery.

(F) Manufacturing Requirements:

(1) Inspection:

The manufacturer of the paint shall advise the Engineer when paint is to be manufactured, shall furnish the Engineer free access to all parts of the plant involved in the paint manufacture, and shall furnish every reasonable facility for sampling both the paint and the raw materials during the process of manufacturing.

All materials used in formulation shall meet the requirements herein specified. Any materials not specifically covered shall meet the approval of the Engineer.

All manufactured paint shall be prepared at the factory ready for application.

When paint is shipped to a distributor or paint applicator who will store the paint prior to its use, the distributor or paint applicator shall furnish the Engineer free access to all parts of the facility where paint is stored and shall furnish every reasonable facility for sampling the paint.

Paint shall normally be sampled at the place of storage either at a warehouse or on the site prior to application of the paint. Application of the paint will not be permitted until the paint has been approved by the Engineer. It is the contractor's responsibility to notify the Engineer a minimum of 14 working days prior to any traffic painting operation and to allow access at that time for paint sampling at the storage location.

A minimum of one paint sample shall be obtained from each lot of paint.

Check-samples of finished paint while being applied will be taken at intervals as determined by the Engineer.

(2) Testing:

All tests will be conducted in accordance with the latest test methods of the American Society for Testing and Materials, Federal Test Method Standard No. 141, and methods in use by the Materials Group, Highways Division, and the Arizona Department of Transportation as specified herein.

Evidence of adulteration or improper formulation shall be cause for rejection.

(3) Packaging:

All shipping containers for paint must comply with the Department of Transportation Code of Federal Regulations, Hazardous Materials and Regulation Board, Reference 49 CFR. The container and lids must be lined with a suitable coating so as to prevent attack by the paint or by agents in the air space above the paint. The lining must not come off the container or lid as skins.

Containers shall be colored white, including lids, and containers shall have an identifying band of the appropriate color around and within the top one third of the container.

All containers shall be properly sealed with suitable gaskets, shall show no evidence of leakage, and shall remain in satisfactory condition for a period of 12 months after delivery to a distributor or paint applicator. The contractor shall be responsible for all costs and transportation charges incurred in replacing paint and containers.

(4) Marking:

All containers of paint shall be labeled showing the manufacturer's name, date of manufacture, paint color, product code, manufacturer's batch number, and quantity or weight of paint on both the side of the container and also the lid. Containers shall be clearly marked or labeled Rapid or Fast Dry lead-free Water-Borne Traffic Paints.

All containers of paint shall be labeled to indicate that the contents fully comply with all rules and regulations concerning air pollution control in the State of Arizona, Maricopa County.

The manufacturer of the paint shall be responsible for proper shipping labels with reference to whether the contents are toxic, corrosive, flammable, etc., as outlined in the U.S. Department of Transportation, Hazardous Materials Regulations, Reference 49 CFR.

(5) Unused Paint:

Disposal of unused quantities of traffic paint shall be the responsibility of the contractor and must meet all applicable Federal regulations for waste disposal. Paint which is saved to be used later shall be packaged as specified previously and shipped to a storage location. Unused paint must be identified on the container. Unused paint may be utilized on a future project provided the paint still conforms to all specifications contained herein.

708-2.02 Reflective Glass Beads (Spheres):

(A) General:

The term "glass bead" shall be synonymous with the term "glass sphere" as used herein.

The beads shall be manufactured from glass of a composition designated to be highly resistant to traffic wear and to the effects of weathering.

The glass beads shall be moisture-proof; contain less than 0.25 percent moisture by weight; and be free of trash, dirt, or other deleterious materials.

Beads shall be essentially free of sharp angular particles showing milkiness or surface scoring or scratching. Beads shall be water white in color.

(B) Physical Requirements:

(1) Gradation:

When tested by the method provided in ASTM D 1214, the grade sizes of the beads shall be as follows:

Size of Sieve	Percent Passing
No. 30	100
No. 50	15 - 35
No. 70	0 - 15
No. 100	0 - 5

(2) Roundness:

When tested by the method provided in ASTM D 1155 (Procedure B except paragraphs (F) and (G) are deleted), beads retained on any screen specified in the gradation requirements shall contain a minimum of 75 percent true spheres.

(3) Index of Refraction:

When tested by a liquid immersion method at a temperature of 25 °C, the beads shall have an index of refraction of 1.50 to 1.57.

(4) Specific Gravity:

The specific gravity of the beads shall be in the range 2.40-2.60 when tested in accordance with the following procedures:

Place 100 grams in an oven at 110 °C for one hour.

Remove beads and place in a desiccator until the sample is cool.

Remove approximately 60 grams of beads from the desiccator and weigh the sample accurately.

Pour the beads slowly into a clean 100-milliliter graduated cylinder containing 50 milliliters of isopropyl alcohol. Make certain that air is not entrapped among the beads.

The total volume, minus 50, will give the volume of the beads.

Calculate the specific gravity as follows:

$$\text{Specific Gravity} = \frac{\text{Weight of the sample}}{\text{Volume of the sample}}$$

(5) Chemical Stability:

Beads which show any tendency toward decomposition, including surface etching, when exposed to atmospheric conditions, moisture, dilute acids, or alkalis or paint film constituents, may be required to demonstrate satisfactory reflectance behavior, prior to acceptance, under such tests as may be prescribed.

(C) Moisture Proofing:

All glass beads shall have a moisture-proof overlay consisting of water repellent material applied during the process of bead manufacture. The beads so treated shall not absorb moisture in storage and shall remain free of clusters and lumps and shall flow freely from dispensing and testing equipment.

The beads shall pass the test for water repellency and free flow using the following equipment:

(1) Test bag:

The bag used is approximately 10-1/2 by 17-1/2 inches after sewing. The material used in the construction of the bag is unbleached cotton sheeting with a thread count of 48 by 48. The material before sewing is approximately 18 by 22 inches. The cloth is folded in half lengthwise and stitched in the shape of an "L" with the short side left open at the top. The material can be obtained from selected manufacturers of cloth and paper packaging. The finished bag may also be obtained from the manufacturer of the glass beads.

Newly fabricated bags must be thoroughly washed with hot water and detergent and rinsed before use to remove the sizing which may be present in the cloth. Subsequent to the initial washing, the bags need only be rinsed clean of beads from previous tests and dried thoroughly before use.

(2) Funnel:

The funnel used is a standard laboratory funnel with a top opening diameter of 125 millimeters and a 150-millimeter stem length. The inside diameter of the stem is between nine and 10 millimeters. This funnel is available from most laboratory glassware supply houses, Corning No. 6100 or equal.

(3) Ring Stand and Clamp.

(4) Balance accurate to 0.1 grams.

(5) Distilled water.

MOISTURE TESTING PROCEDURE:

Glass beads shall be tested for compliance with specification requirements. Testing shall be conducted at standard conditions of temperature ($25 \pm$ one degrees Celsius) and humidity ($50 \pm$ five percent Relative Humidity) and shall consist of the following procedure or an approved alternate:

Weigh 900.0 grams of glass beads into a clean, dry, flat-bottomed pan.

Dry beads at 150°C for two hours.

Cool beads to room temperature ($25 \pm$ one degrees Celsius) in a desiccator.

Using the clean, pre-washed bag described under apparatus section, turn the bag inside-out so that the sewn seam and seam-allowance are on the outside.

Quantitatively transfer the beads into the inverted cotton bag.

Grasp the gathered top of the bag with one hand and lower the bag into a container of distilled water until the beads are approximately one inch below the water level. The container shall be of such dimensions that the bag does not contact the bottom or sides during immersion. Each bag shall be immersed individually. Do not allow one bag to contact another if multiple tests are run.

Remove the bag after 30 seconds of immersion time.

Cradle the bottom of the bag uniformly in the palm of one hand and twist the top neck of the bag until the twisted bag is compressed firmly against the beads. Twist until excess water no longer drips from the bag.

After the excess water has been squeezed from the bag, allow the bag to unwind.

Gather the top of the bag and clamp. Suspend the bag on a ring stand or other support such that the bottom or sides of bag do not contact the support.

After a standing time of two hours at room temperature ($25 \pm$ one degrees Celsius), remove bag from support. Mix sample thoroughly by holding the bottom seam allowance in one hand and gathered neck of the bag in the other, invert bag and shake up and down five times. Transfer the sample into a clean, dry funnel of the type described under apparatus. If consecutive tests are run, be sure the funnel is clean, dry and free of beads from prior tests.

The entire sample shall flow through the funnel without stoppage.

At the start of the test only, it is permissible to lightly tap the stem of the funnel to initiate flow.

Small quantities of beads which have adhered to the side of the funnel or stem shall not be cause for failure.

708-3 Construction Requirements:

708-3.01 Equipment:

The traffic paint and beads shall be placed on the pavement by a spray-type, self-propelled pavement marking machine except that temporary striping during construction may be placed with other equipment designed for application of paint and beads.

The application equipment to be used on roadway installation shall have, as a minimum, the following characteristic and/or apparatus:

The machine shall be capable of applying clear-cut lines of the width specified on the project plans.

The machines shall be equipped with a mechanical device capable of placing a broken reflectorized line with a 10-foot painted segment and a 30-foot gap.

The machine shall be equipped with an air-operated glass bead drop-in dispenser controlled by the spray gun mechanism.

A glass bead dispenser which is capable of placing the glass beads into the paint line as the paint is applied to the pavement shall be utilized. This dispenser shall provide satisfactory marking and delineation.

708-3.02 Application:

Pavement markings shall be applied when the pavement surface is dry and the weather is not foggy, rainy, or otherwise adverse to the application of markings. The surface shall be

free from excess asphalt or other deleterious substances before traffic paint, beads or primer are applied. The contractor shall remove dirt, debris, grease, oil, rocks or chips from the pavement surface before applying markings. The method of cleaning the pavement surface and removal of detrimental material is subject to approval by the Engineer and shall include sweeping and the use of high-pressure air spray. The placing of traffic markings shall be done only by personnel who are experienced in this work.

Painting shall not be performed when the atmospheric temperature is below 50 degrees F when using water-borne paint, nor when it can be anticipated that the atmospheric temperature will drop below said 50 degrees F temperature during the drying period. Water-borne paints shall not be applied if rain is expected within one hour of its application, unless otherwise approved by the Engineer. Water-borne paint shall not be heated to a temperature greater than 150 degrees F to accelerate drying.

The volume of paint in place shall be determined by measuring the paint tank with a calibrated rod. At the option of the Engineer, if the striping machine is equipped with air-atomized spray units (not airless) and paint gauges, the volume of paint may be determined by utilizing said gauges.

The quantity of glass reflectorizing beads in place shall be determined by measuring the glass reflectorizing bead tank with a calibrated rod.

The contractor shall provide the necessary personnel and equipment to divert traffic from the installation area where the work is in progress and during drying time when, in the opinion of the Engineer, such diversion of traffic is necessary.

Tolerances for Placing Paint, Beads, and Primer:

The length of painted segment and gap shall not vary more than six inches in a 40-foot cycle.

The finished line shall be smooth, aesthetically acceptable and free from undue waviness.

Painted lines shall be four, eight, or 12 inches wide as shown on the plans with a tolerance of $\pm 1/8$ inch and shall be placed at a minimum rate of 16 gallons per mile for a solid four-inch line and four gallons per mile for a broken four-inch line, based on a 10-foot stripe and a 30-foot gap (40-foot cycle aggregate).

Glass reflectorizing beads shall be applied on the wet paint at a minimum rate of six pounds per gallon of paint.

Wet thickness shall not be less than 15 mils.

708-4 Method of Measurement:

Pavement marking paint will be measured by the linear foot along the centerline of the pavement stripe. Skips in dashed lines will not be included in the measurement. Length of

pavement markings will be based on four-inch wide stripe. Measurement for striping with a plan width greater or less than the basic four inches as shown on the plans or directed by the Engineer will be made by the following method:

$$\frac{\text{Plan Width of Striping (inches)} \times \text{Linear Feet}}{4 \text{ (inches)}}$$

Symbols and legends will be measured by each unit applied. Each legend, regardless of the number of letters, will be considered as a single unit.

708-5 Basis of Payment:

Pavement striping of the type specified, measured as provided above, will be paid for at the contract price per linear foot for the total length of painted line applied to the nearest foot, which price shall be full compensation for the work complete, including glass beads, as described and specified herein and on the project plans.

Pavement symbols and legends measured as provided above, will be paid for at the contract price for each painted symbol or legend, which price shall be full compensation for the work complete, including glass beads, as described and specified herein and on the project plans.

SECTION 709 DUAL COMPONENT PAVEMENT MARKINGS:

709-1 Description:

The work under this section shall consist of cleaning and preparing pavement surfaces and furnishing and applying either white or yellow reflectorized dual component pavement markings to the prepared pavement at the locations and in accordance with the manufacturers specifications, the details shown on the project plans and the requirements of these specifications. The type of dual component marking system, marking configuration and thickness shall be in accordance with the project plans and these specifications.

709-2 Materials:

709-2.01 General Requirements:

The dual component pavement marking material shall be a liquid or 100 percent solids epoxy or other dual component UV-stabilized system, formulated and designed to provide a simple volumetric mixing ratio of the two components (resin and catalyst). The characteristics of the material shall be such that complete and even coverage of specified areas to the required thickness is provided by the required application method and rate. Upon drying the dual component material shall produce an adherent durable reflectorized marking capable of resisting deformation and wear in the roadway. The material shall be suitable for application to old and new asphaltic concrete and Portland cement concrete pavement surfaces.

A list of approved manufacturers of dual component pavement marking material is shown on the Department's Approved Products List. Copies of the most current version are available on the internet at <http://www.dot.state.az.us/ABOUT/atrc/apl.htm>.

709-2.02 Epoxy Composition Requirements:

Epoxy pavement marking material shall conform to the following requirements:

(A) Composition:

The epoxy resin material shall be within the following compositional requirements:

Component	Percent by Weight	
	White	Yellow
White Pigment (Titanium Dioxide)	18 min.	---
Yellow Pigment	---	23 - 30
Epoxy Resin	75 - 82	70 - 77

(B) Epoxide Number:

The epoxide number of the epoxy shall be determined in accordance with ASTM D 1652 for both white and yellow resin material on a pigment free basis. The epoxide number shall be within ± 50 of the published manufacturers standard for the approved product.

(C) Amine Number:

The amine number of the curing agent shall be determined in accordance with ASTM D 2074. The amine number shall be within ± 50 of the published manufacturers standard for the approved product.

(D) Toxicity:

Upon heating to application temperature, the material shall not exude fumes which are toxic or injurious to persons or property.

(E) Adhesion to Concrete:

The epoxy marking materials, when tested according to ACI Method 503, shall have a higher degree of adhesion to the specified concrete (4,000 pounds per square inch, minimum) surface, such that there shall be a 100 percent concrete failure in the performance of this test. The samples shall be allowed to cure at room temperature (75 ± 2 degrees F,) for a minimum of 24 hours and a maximum of 72 hours prior to performing the indicated tests.

(F) Hardness:

The epoxy paint pavement markings material, when tested according to ASTM D 2240, shall have a Shore D Hardness of between 70 to 95. The samples shall be allowed to cure at room temperature (75 ± 2 degrees F) for a minimum of 24 hours and a maximum of 72 hours prior to performing the indicated tests.

(G) Abrasion Resistance:

The abrasion resistance shall be evaluated on a Taber Abrader with a 1,000 gram load and CS-17 wheels. The duration of the test shall be 1,000 cycles. The wear index shall be calculated based on ASTM C 501, and the wear index for the dual component material shall not be more than 90 milligrams. The test shall be performed on cured samples of material which have been applied, without glass beads, at a film thickness of 0.020 ± 0.0005 inches to code S-16 stainless steel plates. The samples shall be allowed to cure at room temperature (75 ± 2 degrees F) for a minimum of 24 hours and a maximum of 72 hours prior to performing the indicated tests.

(H) Tensile Strength:

When tested in accordance with ASTM D 638, the epoxy marking materials shall have an average tensile strength of not less than 6,000 pounds per square inch. The Type IV specimens shall be cast in a suitable mold and pulled at a rate of 1/4 inch per minute by a suitable dynamic testing machine. The samples shall be allowed to cure at room temperature (75 ± 2 degrees F) for a minimum of 24 hours and a maximum of 72 hours prior to performing the indicated tests.

(I) Compressive Strength:

When tested according to ASTM D 695, the epoxy pavement marking materials shall have an average compressive strength of not less than 11,000 pounds per square inch. The samples shall be allowed to cure at room temperature (75 ± 2 degrees F) for a minimum of 24 hours and a maximum of 72 hours prior to performing the indicated tests.

(J) Retroreflectance:

White and yellow dual component marking materials shall have the following minimum retroreflectance values at 86.5 degrees illumination angle and 1.5 degrees observation angle as measured by a Mirolux 12 portable retroreflectometer. The readings shall taken from sample plates of markings applied in the field on the project to the specified thickness and bead application rate. The contractor and Engineer shall coordinate on procedures for sampling and handling of samples.

Product	Retroreflectance (Millicandelas)
White	200
Yellow	501

Additionally, all white and yellow markings placed in the field shall also exhibit the same minimum retroreflectance values 30 days after application to the roadway surface.

Markings not complying shall be removed and replaced at no additional cost to the Department.

(K) Color:

The colors of the applied markings shall conform to the following requirements:

The white color shall match Federal Test Standard Number 595B, color chip no. 37875.

The yellow color shall match Federal Test Standard Number 595B, color chip no. 33583.

(L) Yellowness Index:

The white material shall not exceed a yellowness index of 23 when tested in accordance with ASTM D 1925. The index shall be based on a sample which has been cured for 72 hours at room temperature (75 ± 2 degrees F) and exposed in the QUV chamber for 72 hours.

(M) Viscosity:

The formulations of each component part shall be such that the viscosity of both parts, when measured in accordance with ASTM D 2196, Method A, shall be within 10 percent of each other at the recommended spray temperature.

(N) Curing and No-Track Time:

No-track time shall be defined as the time necessary for the epoxy marking to cure to a no-track condition. The epoxy marking, when properly applied with the required gradations and bead application rates per gallon, shall cure to a no-track condition, when tested in accordance with ASTM D 711, within 30 minutes at 40 degrees F, and no more than 20 minutes at temperatures of 70 degrees F or more.

The applied epoxy material shall be capable of fully curing at a minimum pavement surface temperature of 32 degrees F. At room temperature (75 ± 2 degrees F), a sample shall be capable of curing to full strength in 72 hours.

(O) Storage Life:

The materials shall meet the requirements of this specification for a period of at least one year from the date of manufacture. The month and year of manufacture shall be clearly marked on all containers. Product MSDS information shall be attached to material containers at all times. Any material which does not meet the above requirements, or which is no longer within this one-year period at the time of application, shall not be used unless approved by the Engineer. The contractor shall replace any outdated material with material meeting the above performance and time requirements at no additional cost to the Department.

(P) Testing and Certificates:

When requested by the Engineer, the contractor shall provide liquid samples of the catalyst and resins in appropriate containers for testing. Certificates of Analysis conforming to Subsection 106.05 shall be submitted for all materials, and shall include the Material Safety Data Sheets (MSDS).

709-2.03 Glass Beads:

The glass beads shall be colorless, transparent, free from milkiness or excessive air bubbles, and essentially clean from surface scarring or scratching. They shall be spherical in shape, and at least 70 percent are to be true spheres when tested in accordance with ASTM D 1155, Procedure A. The refractive index of the spheres shall be a minimum of 1.5 as determined by the liquid immersion method A 25 DC. The silica content of the glass beads shall not be less than 60 percent. The beads shall have the following gradation when tested in accordance with ASTM D 1214:

TYPE A GLASS BEADS (Large Bead)	
Sieve No.	% Retained
10	0
12	0 - 5
14	5 - 25
16	40 - 80
18	10 - 40
20	0 - 5
Pan	0 - 2

TYPE B GLASS BEADS (Small Bead)	
Sieve No.	% Retained
20	0 - 5
30	5 - 25
50	30 - 75
80	9 - 32
100	0 - 5
Pan	0 - 2

The Type A and B glass beads shall have a moisture-proof coating, and shall be dual-coated with a silane-type adherence coating. The glass beads shall display no tendency to absorb moisture in storage, and shall remain free of clusters and lumps. The beads shall flow freely from dispensing equipment at the time of application. The moisture-resistance of the glass beads shall be determined in accordance with Subsection 708-2.02 (C).

Certificates of Analysis conforming to the requirements of Subsection 106.05 shall be submitted for the glass beads to be used on the dual component pavement marking systems. The certificate shall also include a Material Safety Data Sheet (MSDS).

709-3 Construction Requirements:

709-3.01 Equipment:

The pavement marking equipment for longitudinal lines shall have a system capable of spraying both yellow and white dual component pavement markings. The marking vehicle shall be of sufficient size and stability with an adequate power supply to produce lines of uniform dimension, with square edges, and proper mix of the two component parts to ensure proper application. The equipment shall be capable of placing markings and applying glass beads at both the left and right sides of the truck, and placing two lines simultaneously with either line in a solid or intermittent pattern in either yellow or white. All sprayers shall be in full view of the operators at all times. The equipment shall be provided with a metering device to register the accumulated installed pavement marking for each sprayer, each day. The contractor shall provide a certificate from the American Traffic Safety Services Association (A.T.S.S.A.), or equivalent documentation, to the Engineer to verify that the driver and operator of the application truck are fully trained and experienced in the application of the dual component marking system being applied. The equipment shall include pressure gauges for each proportioning pump which are visible to the operator at all times, so that any fluctuations can be detected immediately during the marking operations.

The longitudinal line application vehicle shall be equipped with high pressure air spray jets in front of the striping material and glass bead applicators to remove loose matter on the pavement surface where the marking material is to be applied.

The vehicle shall be equipped with two separate glass bead supply tanks and two glass bead dispensers per each marking material sprayer. The contractor shall provide documentation to the Engineer that bead dispensers are specifically manufactured for the glass bead application rates contained herein. When Type A gradations of glass beads are applied, the vehicle shall be equipped with high-capacity cone-shaped pressure or gravity dispensers. All bead dispenser outlets shall have enclosed wind shrouds or equivalent devices to direct the glass beads as they are applied. The shroud may include an opening which faces the operator so that the flow rate of the glass beads can be monitored. The bottom of the shroud shall be mounted within three to four inches of the pavement surface and be configured to allow for even distribution of glass beads on the applied markings.

Equipment for the application of transverse lines, longitudinal lines less than 200 in length, legends and symbols shall be either a hand wand attachment to a longitudinal line application vehicle, or a separate motorized trailer application system. Application equipment for short or transverse lines, legends, and symbols can be suitable for only one color.

709-3.02 Application:

(A) Placement Locations:

Dual component pavement markings shall be as shown on the plans, except that marking lines shall not be placed on parallel construction or expansion joints. Longitudinal lines

shall be offset to provide a minimum of one inch of clearance from parallel construction and expansion joints unless otherwise directed by the Engineer.

(B) Material Inspection:

All dual component pavement marking materials and glass beads will be inspected and approved by the Engineer prior to their application. The contractor shall also provide samples of said materials if requested by the Engineer.

All materials shall be properly packaged and stored. Each container to be used on the project shall be clearly labeled to indicate the following information (as applicable):

- Nature, type, color and formulation of the material;
- Manufacturer, batch number and date of manufacture;
- Application requirements and constraints; and
- MSDS information.

Storage, preparation and application equipment shall be in accordance with the plans, specifications and the recommendations of the materials manufacturer.

The contractor shall dispose of excess materials, spilled materials, cleaning fluids and all empty material containers at a site approved by the Engineer.

(C) Equipment Inspections and Deficiencies:

The contractor shall make daily maintenance and operation inspections of all application equipment to ensure that it is operable with the requirements of the specifications. The contractor shall inform the Engineer of any equipment breakdowns, intermittent malfunctions or other conditions that may impact the proper application of specified markings. Any equipment judged to be unsuitable by the Engineer shall be repaired or replaced.

(D) Pavement Surface:

The contractor shall remove all dirt, dust, grease, oil or other detrimental material from the road surface prior to application of the dual component material.

Existing temporary or permanent traffic markings shall be removed by abrasive blasting or grinding until a minimum of 85 percent of the underlying pavement is visible, unless otherwise recommended by the materials manufacturer. The method of abrasive blasting and grinding is subject to approval by the Engineer. The contractor shall clean the surface by sweeping and with high-pressure air spray, unless otherwise recommended by the materials manufacturer. The contractor shall minimize any interference between temporary pavement markings and the permanent dual component pavement markings.

When dual component markings are to be applied to new Portland cement concrete pavement, any curing compound present shall be removed by means of a high-pressure water jet or sandblasting, followed by sweeping and high-pressure air spray. The curing

compound shall be removed at least one inch beyond the width of the marking to be installed.

(E) Pavement Temperature and Condition:

Dual component pavement markings shall not be applied to new asphaltic concrete pavements for a minimum of 30 days after the pavement has been placed.

The roadway surface temperature at the time of application shall be a minimum of 40 degrees F and shall be rising. The air temperature and wind chill factor shall not be below 35 degrees F. Additionally, the road surface shall be dry with no standing water or significant surface dampness or dew.

The pavement surface temperatures shall be measured one half hour prior to the start of the striping installation activities, and every one to two hours after that until the end of the day if the temperature is judged by the Engineer to be critical. For elevation changes greater than 1,000 feet, temperature readings at the highest elevation shall govern unless otherwise directed by the Engineer. The pavement surface temperature shall be measured with a standard surface temperature or an infrared non-contact thermometer. The Engineer may require temperature readings to be taken at shorter time intervals.

(F) Application Calibration Requirements:

Prior to the start of all marking application operations, the film thickness, width and bead application rates shall be calibrated as specified below in the presence of the Engineer. If at any time a condition changes, or the required application rates are not being achieved, the contractor shall repeat the calibration process if so directed by the Engineer.

(1) Film Thickness and Width Calibration for Longitudinal Lines:

The required application speed for the pavement marking vehicle shall be determined prior to the start of each day's marking operations.

The equipment needed to calibrate paint wet film thickness and width are a stopwatch, metal sample plates 4 by 12 inches minimum, wet film thickness gauge, measuring tape, and a roll of tar paper. The paint film application thickness, width and speed shall be calibrated using the following procedure:

- Step 1 - A 30-foot length of four foot wide tar paper shall be rolled out and attached to the pavement in an area where the striping vehicle can achieve and maintain a speed of up to ten miles per hour without impacting traffic. The tar paper shall be secured to the pavement surface with duct tape so that it is laying flat. Three metal sample plates shall be placed three to four feet (apart and duct-taped down near the end of the 30-foot test distance.
- Step 2 - The striping vehicle shall install a stripe, without glass beads, on the tar paper for the marked 30-foot distance and over the sample plates. The time that it takes the striping vehicle to apply the 30 feet (of test stripe shall be measured

and then equated to a mile per hour application speed. Additionally, the velocity of the striping vehicle shall be noted by the driver. The contractor shall remove any test stripes which extend beyond the tar paper.

- Step 3 - Immediately after the test stripe has been installed, the wet film thickness on all three metal plates shall be measured, as specified in ASTM D 1212, using a wet film thickness gauge. The device shall be inserted into the wet paint to the depth of the metal, in accordance with the manufacturer's recommendations, and the thickness visually noted. If a wet thickness gauge is used, the manufacturer's directions shall be followed. The stripe distribution on the sample plates will be inspected for width, edge definition, and overall visual appearance.
- Step 4 - Steps 2 and 3 shall be repeated until the optimum paint application speed, material flow settings, and sprayer heights are determined, and the atomizing pressures are established, such that an even clearly-defined stripe of the required width and thickness is produced.

Additionally, spot checks of the applied wet film thickness shall be made by the contractor throughout the day. Random spot checks of the paint thickness will also be made by the Engineer to ensure conformance with the required criteria. The contractor shall inspect the wet film thickness immediately after the marking paint is applied by inserting a wet film thickness gauge, with graduations of 0.001 inch into the wet paint to the depth of the pavement surface, in accordance with ASTM D 1212. The thickness determined through spot checking shall be within 0.002 inches of the required thickness.

If the applied thickness is not within the tolerance specified above, or the width of the line is less than required, all striping operations shall stop, and adjustments shall be made such that the required thickness or width is achieved. If after three consecutive adjustments the required width or thickness are still not being achieved, all striping operations shall be halted and the contractor shall repeat the calibration procedures herein specified before striping operations can start again.

(2) Glass Bead Flow Calibration for Longitudinal Lines:

The glass bead application rates shall be calibrated at the beginning of each day's marking operation, after the marking paint application speed has been determined.

The equipment needed to calibrate the bead flow is a stopwatch, 1000-milliliter beaker graduated at 50-milliliter intervals, a bead calibration chart (available from glass bead manufacturers), and two 5-gallon buckets. The bead calibration charts shall equate the volume of beads measured through the calibration process to the required glass bead application rate in pounds per gallon of dual component marking paint applied. The chart shall also include the required application speed in miles per hour to achieve the specified glass bead application rate. The glass bead application rate shall be calibrated using the following procedure:

- Step 1 - With the striping vehicle stopped and the paint sprayer off, place a bucket under the bead dispenser.
- Step 2 - Turn the bead dispenser on for five seconds.
- Step 3 - Pour the beads into the beaker and measure the volume.
- Step 4 - Using the bead calibration chart for the required thickness of paint, find the required bead application rate, the measured volume of beads in the beaker, and the resulting application speed.
- Step 5 - If the beaker volume is less than the chart value, increase the bead flow. If the beaker volume is more than the chart value, decrease the bead flow.
- Step 6 - Repeat Steps 2 through 5 until the required speed for the specified bead application rate matches the required paint application speed as determined in 709-3.02(F)(1).

Once all application speed and settings have been calibrated, the contractor shall lay a test strip of the dual component paint marking at the specified width, thickness, and glass bead density. The test strip shall be placed on a 20-foot length of 4-foot wide tar paper, with two 4 by 12-inch sample plates spaced ten feet apart. The contractor shall provide the two sample plates from the test strip to the Engineer. The plates shall indicate the date, project number, project name, thickness, bead application rate and contractor name on the back. The Engineer may have these plates tested per the requirements of Subsection 709-2.02(J). All calibration activities shall be done in the presence of the Engineer.

(3) Thickness and Glass Bead Calibration for Transverse Markings, Symbols and Legends:

Calibration of thickness for transverse markings, symbols and legends prior to construction will not be required. The contractor shall inspect the wet film thickness immediately after the marking paint is applied by inserting a wet film thickness gauge, with graduations of 0.001 inch, into the wet paint to the depth of the pavement surface, in accordance with ASTM D 1212. The thickness determined through spot checking shall be within 0.002 inches of the required thickness. Random spot checks of the marking thickness will also be made by the Engineer to ensure conformance with the required criteria.

Bead application rates shall be determined by pre-weighing, in a clearly marked container, the amount of beads required for each transverse marking, symbol or legend. The contractor shall determine the amount of beads required for each individual application, and provide documentation to the Engineer for approval prior to application.

(G) Marking Application:

The standard application thickness and bead gradations types and rates for dual component markings shall be as follows:

(1) Longitudinal Lines:

(a) Standard:

For asphaltic concrete pavements placed at elevations under 4,000 feet, dual component markings shall be 0.025 ± 0.002 inches thick with a bead application rate of 8 pounds of Type A glass beads per gallon of paint, followed immediately with 8 pounds of Type B glass beads per gallon of paint. For asphaltic concrete pavements placed at elevations equal to or above 4,000 feet, the thickness shall be the same; however, the bead application rate shall be 26 pounds of Type B glass beads per gallon of paint.

For PCCP pavements placed at elevations under 4,000 feet, dual component markings shall be 0.020 ± 0.002 inches thick with a bead application rate of 9 pounds of Type A glass beads per gallon of paint, followed immediately with 9 pounds of Type B glass beads per gallon of paint. For PCCP pavements placed at elevations equal to or above 4,000 feet, the thickness shall be the same; however, the bead application rate shall be 24 pounds of Type B glass beads per gallon of paint.

(b) Special (when shown on the bidding schedule):

For asphaltic concrete pavements placed at elevations under 4,000 feet, dual component markings shall be 0.020 ± 0.002 inches thick with a bead application rate of 9 pounds of Type A glass beads per gallon of paint, followed immediately with 9 pounds of Type B glass beads per gallon of paint. For asphaltic concrete pavements placed at elevations equal to or above 4,000 feet, the thickness shall be the same; however, the bead application rate shall be 24 pounds of Type A glass beads per gallon of paint.

No reductions in thickness will be allowed for PCCP pavements.

(2) Transverse Lines, Symbols, and Legends:

The thickness of dual component pavement markings for transverse lines, symbols, and legends shall be 0.025 ± 0.002 inches with a bead application rate of 26 pounds of Type A beads per gallon of paint for all surfaces and at any elevation.

An epoxy application thickness of 0.025 ± 0.002 inches may be allowed on bridge decks if the majority of the project is AC pavement, and if approved by the Engineer. No additional payment will be made for the increased thickness if so allowed.

For longitudinal lines, the drop-on glass beads shall be mechanically deposited, at the specified rates, into the dual component marking material immediately after it is applied. The bead dispenser device shall evenly distribute the beads such that the top layer of beads are embedded in the surface of the marking to a depth of 50 to 60 percent of the bead diameter. Should the glass beads not adhere, or the top layer sink into the marking beyond the required embedment depth, operations shall be stopped until the problem has been corrected. All markings which do not meet the requirements of Subsection 709-2.02(J) shall be removed and replaced by the contractor at no additional cost to the Department.

Transverse lines, longitudinal lines less than 200 feet in length, legends and symbols shall be applied with a hand wand attachment to a longitudinal line application vehicle, or with a separate motorized trailer application system. Pre-cut templates shall be used for all short or transverse lines, legends, and symbols, and shall provide neat and square marking edges. Beads shall be hand-applied, and shall be evenly distributed over the markings using pre-measured buckets.

The finished dual component marking line shall have well-defined edges and be free from waviness. Lateral deviation of the marking line shall not exceed one inch in 100. The longitudinal deviation of a marking line and gap shall not vary more than six inches in a 40 foot cycle. The actual width of marking line shall be within the limits specified in the following table, according to the width of line called for on the plans:

Plan Width	Actual Width
4 inches	4 to 4-1/2 inches
8 inches	8 to 9 inches
Over 8 inches	± 1 inch

After application and sufficient drying time, the dual component marking shall show no appreciable deformation or discoloration under local traffic conditions in an air or road temperature ranging from -10 to + 180 degrees F. The drying time shall be defined as the minimum elapsed time, after application, when the dual component pavement markings shall have and retain the characteristics required herein, and after which normal traffic will leave no impression or imprint on the newly applied marking. Drying time for epoxy materials shall be defined as the no-track time as specified in Subsection 709-2.02(N).

The contractor shall protect the newly applied dual component pavement markings from traffic during the required drying time.

(H) Material Applied:

The contractor shall provide a full accounting of all marking material and glass beads applied. Prior to the start of striping operations and after the calibration procedures, the contractor shall provide the Engineer with a detailed quantity summary which specifies the gallons of marking material and pounds of glass beads needed to achieve the specified marking configuration. The contractor shall record these quantities each day in a log book. The Engineer and contractor will monitor the quantity of beads and paint applied each day, and compare the values to the anticipated quantity. The quantities of paint and beads actually applied shall be within ± five percent of the anticipated calculated values for each day's striping operation. The contractor shall determine the cause of any larger variations, and make necessary corrections before the next striping application shift. The log book quantities shall be agreed on after each day, and signed and dated by both the contractor and the Engineer.

709-4 Method of Measurement:

Dual component white and yellow longitudinal pavement markings, and transverse markings such as cross-walks and stop bars, will be measured by the linear foot along the center line of the pavement stripe, and will be based on a four-inch wide stripe. Skips in dashed lines will not be included in the measurement. Measurement for striping with a plan width greater or less than the basic four inches, as shown on the plans or directed by the Engineer, will be made by the following method:

$$\frac{\text{Plan Width of Striping, (inches)} \times \text{Linear Feet}}{4 \text{ (inches)}}$$

Double marking lines, consisting of two four-inch wide stripes, will be measured as two individual marking lines. Crosswalk lines, stop bars, stop lines, gore lines, cross hatch lines, chevron lines and railroad marking transverse lines will be measured for centerline length and adjusted for widths other than four inches, as defined above.

Dual component pavement marking symbols, such as a diamond, or single, double, or triple arrow, will be measured by the unit applied. Each pavement symbol, as shown on the plans, will be considered a unit.

Dual component pavement marking legends, defined as a complete letter grouping such as "SCHOOL," "XING," "STOP," "RR," or "ONLY," will be measured by each unit applied. Each pavement legend, as shown on the plans, will be considered a unit.

No separate measurement or payment will be made for cleaning the surface, including sweeping and high-pressure air spray; or for calibration of the bead and paint application rates; or for disposal of excess materials, cleaning fluids, and empty material containers; the costs being considered as included in the contract items.

Removal of curing compound from new Portland cement concrete pavement shall be measured by the linear foot for striping lines regardless of width, or unit each for symbols and legends, in accordance with the items of work established in the bid schedule.

The cost for abrasive-blasting and grinding existing markings, not including temporary paint or tape lines, shall be paid for under separate items. No separate payment will be made for removing temporary paint or tape lines, the cost being considered as included in contract items.

709-5 Basis of Payment:

The accepted quantities of dual component pavement markings of the type specified in the bidding schedule, measured as provided above, will be paid for at the contract unit price, complete in place, including pavement surface preparation and glass beads.

The accepted quantities for removal of curing compound from new Portland cement concrete pavement, measured as provided above, will be paid for at the respective contract unit prices, under the items of work established in the bid schedule.

SECTION 710-729 BLANK

SECTION 730 GENERAL REQUIREMENTS FOR TRAFFIC SIGNAL AND HIGHWAY LIGHTING SYSTEMS:

730-1 Description:

It is the purpose of this section to provide general information necessary for completion of the work on traffic signal and highway lighting systems in accordance with the details shown on the project plans and requirements of these specifications.

All electrical systems and appurtenances shall be complete, functional and in operating condition at the time of acceptance.

730-2 Definitions:

The words defined in the following subsection shall for the purpose of these specifications have the meanings ascribed to them pertaining to signals and lighting.

730-2.01 Actuation:

The operation of any type of controller initiated by a detector.

730-2.02 Back Plate:

A thin metal strip extending outward parallel to the signal face on all sides of a signal housing to provide suitable background for the signal indications.

730-2.03 Controller:

That part of the controller assembly which performs the basic timing and logic functions for the operation of the traffic signal.

730-2.04 Controller Assembly:

The complete assembly for controlling the operation of a traffic signal, consisting of a controller unit, and all auxiliary and external equipment housed in a weatherproof cabinet.

730-2.05 Cycle:

A complete sequence of signal indications.

730-2.06 Detector:

A device for indicating the passage or presence of vehicles or pedestrians.

(A) Inductive Loop Detector:

A detector capable of sensing the passage or presence of a vehicle by a change in the inductance characteristics of the wire loop.

(B) Magnetometer Vehicle Detector:

A detector capable of being actuated by the magnetic disturbance caused by the passage or presence of a vehicle.

(C) Pedestrian Detector:

A detector, for pedestrians, usually of the button type.

730-2.07 Flasher:

A device used to open and close signal circuits at a repetitive rate.

730-2.08 Flashing Feature:

This feature, when operated, discontinues normal signal operation and causes a predetermined combination of flashing signal lights.

730-2.09 Interval:

The part or parts of the signal cycle during which signal indications do not change.

730-2.10 Luminaire:

The assembly which houses the light source and controls the light emitted from the light source. Luminaires consist of a housing, lamp socket, reflector, and glass globe or refractor when specified.

730-2.11 Manual Operation:

The operation of a signal controller unit by means of a hand-operated switch.

730-2.12 Mounting Assembly:

The framework and hardware required to mount the signal face(s) and pedestrian signal(s) to the pole.

730-2.13 Pedestrian Signal:

A traffic control signal for the exclusive purpose of directing pedestrian traffic at signalized locations.

730-2.14 Pretimed Controller Assembly:

A controller assembly for operating traffic signals in accordance with a predetermined fixed-time cycle.

730-2.15 Red Clearance Interval:

A clearance interval which follows the yellow change interval during which both the terminating phase and the next right-of-way phase display red.

730-2.16 Signal Face:

An assembly controlling traffic in a single direction and consisting of one or more signal sections. Circular and arrow indications may be included in a signal assembly. The signal face assembly shall include the backplate and visors.

730-2.17 Signal Indication:

The illumination of a signal section or other device, or of a combination of sections or other devices at the same time.

730-2.18 Signal Section:

A complete unit for providing a signal indication consisting of a housing, lens, reflector, lamp receptacle and lamp.

730-2.19 Traffic Phase:

A part of the time cycle allotted to any traffic movement or combination of movements receiving the right-of-way during one or more intervals.

730-2.20 Traffic-Actuated Controller Assembly:

A controller assembly for operating traffic signals in accordance with the varying demands of traffic as registered with the controller unit by detectors.

730-2.21 Vehicle:

Any motor vehicle normally licensed for highway use.

730-2.22 Yellow Change Interval:

The first interval following the green right-of-way interval in which the signal indication for the phase is yellow.

730-3 Regulations and Codes:

All electrical equipment shall conform to the current standards of National Electrical Manufacturers Association (NEMA), National Electric Safety Code (NESC), Underwriters' Laboratory Inc. (UL), or the Electronic Industries Association (EIA), when applicable. All

materials and workmanship shall conform to the requirements of the National Electric Code (NEC), Illumination Engineers Society (IES), the American Society for Testing and Materials (ASTM), American Association of State Highway and Transportation Officials (AASHTO), requirements of the plans, these specifications, and the Special Provisions, and to any other codes, standards, or ordinances which may apply. Whenever reference is made to any of the standards mentioned, the reference shall be construed to mean the code, ordinance, or standard that is in effect at the time of the bid advertisement.

730-4 Equipment List and Drawings:

The contractor shall note that approval by the Engineer is required before ordering or installing any material that is to be used on the project.

The contractor shall submit six copies of a complete project material submittal for approval at the pre-construction conference which shall conform to these specifications. The project material submittal shall state all relevant information regarding materials and equipment to allow the Department to procure exact replacements of any or all items on the project. To be acceptable, the material submittal shall be complete and contain all items supplied on the project by the contractor. The Department reserves the right to reject an incomplete or unclear material submittal.

The materials on the submittal shall be identified by the contract project number, bid item numbers, catalog part numbers, catalog cuts, shop drawings for signal and lighting equipment, trade names, schedules for other pertinent information. The materials from any catalog cuts shall be clearly indicated by the contractor. Any material designations used in the contract documents shall be so noted on the materials list. If requested by the Engineer, the contractor shall submit manufacturer shop drawings for review and approval and shall furnish Certificates of Compliance conforming to the requirements of Subsection 106.05.

There shall be no substitutions for any of the materials on the list without prior written approval by the Engineer. Changes to the approved materials list shall be submitted in writing to the Engineer. If requested by the Engineer, the contractor shall submit samples of the proposed materials for inspections, testing, and approval by the Department. The Department will not be liable for any electrical materials procured or any labor performed prior to approval.

When the plans include lighting, the contractor shall submit six copies of photometric data sheets indicating the IES distribution classification for each type of luminaire submitted for approval. In addition, the contractor shall submit data from the manufacturer detailing lamp socket positions in relation to lamps and optical systems furnished for each IES distribution type specified. If required by the Special Provisions, the contractor shall provide computer printout grids of both luminance and illuminance values for the spacing, height, roadway width, and type of luminaire submitted.

The contractor shall provide complete wiring diagrams for controller assemblies and auxiliary controller cabinets at the time of delivery for testing. A mylar original and four sets of prints shall be provided with each controller assembly. The wiring diagram shall illustrate

all circuits and components in detail. All components shall be identified by name or number so as to be clearly noted in the drawings.

730-5 Warranties & Guaranties:

Manufacturer's warranties and guaranties, furnished for materials and equipment used in the work, shall be delivered to the Engineer prior to acceptance of the project. Warranties and guaranties shall conform to the requirements of Subsection 106.13.

730-6 Locations of Utilities:

The locations of utilities shown on the project plans are approximate. All involved utilities may not be shown on the plans.

In addition to the requirements of Subsection 107.15, the contractor's attention is directed to the requirements of A.R.S. 40-360.21 through .29 requiring all parties excavating in public streets, alleys or utility easements to first secure the locations of all underground facilities in the vicinity of the excavation.

The contractor shall contact the Blue Stake Center at least two working days prior to commencing excavation, for information relative to the location of buried utilities within the project limits.

SECTION 731 STRUCTURAL SUPPORTS AND FOUNDATIONS FOR TRAFFIC SIGNAL AND HIGHWAY LIGHTING:

731-1 Description:

The work under this section shall consist of furnishing all materials and constructing new supports and foundations for traffic signal and highway lighting systems or modifying poles and mast arms of existing systems at the locations shown on the project plans and in accordance with the details shown on the plans and the requirements of these specifications.

Pole foundations shall include all conduit, elbows, anchor bolts, grounding wire and reinforcing steel. Cabinet foundations shall include conduit, elbows, anchor bolts and clearance pad.

731-2 Materials:

Excavation and backfill shall conform to the requirements of Subsection 203-5.03. Concrete shall conform to the requirements of 1006 and 601. Reinforcing steel and wire mesh shall conform to the requirements of 1003 and 605.

Concrete for all foundations shall be Class S and shall have a required 28-day compressive strength of 3,000 pounds per square inch.

731-2.01 Blank

731-2.02 Standard Steel Poles:

(A) General:

Standard steel poles for traffic signals and highway lighting shall include pole shafts and pole bases.

Material standards for traffic signal and lighting supports shall be in conformance with the current edition of the AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals. All pole supports shall be designed to withstand 70-mile per hour winds except for the type K and R poles. The type K & R poles shall be designed to withstand 80-mile per hour winds. Metal parts of standard steel poles and hardware shall conform to the details shown on the plans and the following specifications. Welding shall conform to the requirements of Subsection 604-3.06.

(B) Pole Shafts:

Tapered pole shafts shall be fabricated from sheet steel of weldable grade which shall meet or exceed the minimum strength requirements of ASTM A 36, for all poles except the type K and R poles. The type K and R poles shall be constructed from sheet steel that has a minimum yield stress, after fabrication, of 48,000 pounds per square inch. A taper rate of 0.14 inches in diameter per linear foot shall be required unless otherwise specified. Pole shafts shall be fabricated according to the thickness requirements shown on the plans.

Standard pipe pole shafts shall be fabricated from standard weight structural steel which conforms to the minimum strength requirements of ASTM A 53, Grade B, and a nominal diameter indicated on the Standard Drawings. Each section shall be fabricated from not more than two pieces of sheet steel. When two pieces are used, the longitudinal welded seams shall be directly opposite one another. When the sections are butt-welded, seams shall be directly opposite one another. When the sections are butt-welded together, the longitudinal welded seams on adjacent sections shall be placed to form continuous straight seams from base to top of pole. Pole shafts shall be straight, with a permissive variation not to exceed one inch measured at the midpoint.

Pole shafts shall be galvanized in accordance with the requirements of ASTM A 123. The visual appearance of the galvanized finish shall be uniform. Discoloration of the galvanized finish such as dark areas, dark streaks, dark rings or transportation handling marks which are considered excessive by the Engineer shall not be allowed. Pole shafts that have a finish unacceptable to the Engineer shall either be repaired or replaced to the satisfaction of the Engineer at no additional cost to the Department.

Hand holes in the base of the poles shall conform to the details shown on the Standard Drawings. All welds shall be continuous and any exposed welds, except fillet welds, shall be ground flush with the base metal.

A metal tag shall be permanently attached to the pole above the hand hole stating the manufacturer's name, pole type per the Department's plans, pole drawing number, shaft length and gage number.

(C) Steel Pole Extensions and Twin Luminaire Brackets:

Pole extensions and twin luminaire brackets shall be fabricated from new pipe conforming to the requirements of ASTM A 53. All welding shall conform to the requirements of Subsection 604-3.06. Pole extensions and twin luminaire brackets shall be fully galvanized in accordance with the requirements of ASTM A 123. Fabrication of the pole extensions and twin luminaire brackets shall be in accordance with the dimensions as specified in the plans.

(D) Standard Bases:

Poles shall have standard bases unless break-away or slip-away bases are specified. Standard bases shall be fabricated from structural steel plates conforming to the minimum strength requirements of ASTM A 36. Exposed surfaces shall be finished smooth and all exposed edges shall be neatly rounded to a 1/8-inch radius. Standard bases shall be galvanized in accordance with the requirements of ASTM A 123.

(E) Slip-Away Bases:

Slip-away bases shall be fabricated from structural steel conforming to the requirements of ASTM A 36. Exposed surfaces shall be finished smooth and all exposed edges shall be neatly rounded to a 1/8-inch radius. Slip-away bases shall be galvanized in accordance with the requirements of ASTM A 123 and shall have all the necessary hardware to make a complete and functioning unit. High strength flat washers, bolts and nuts used to connect slip-away base plates shall conform to the requirements of ASTM A 325 and shall be electro-galvanized in accordance with the requirements of ASTM B 633. Slip-away bases shall be used on roadway lighting poles where specified on the plans.

(F) Break-Away Bases:

Break-away bases shall be fabricated from 365 T4 or SG 70AT6 aluminum alloy. The base shall be heat-treated in accordance with the requirements of ASTM B 108, temper designation T6, before shipment. The break-away base shall have all the necessary hardware to make a complete and functional unit. Bolts, washers and nuts shall meet or exceed ASTM A 36 minimum strength requirements and shall be fully galvanized in accordance with ASTM A 153.

Break-away bases shall be certified by the manufacturer to meet or exceed the change in momentum requirements of the AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals, and to be acceptable for use on Federal Aid projects. The manufacturer shall also certify that the break-away base has been tested and approved by the Federal Highway Administration and that the castings have the same chemistry, mechanical properties, and geometry as the castings used in the tests.

Break-away bases shall be used where specified on the project plans.

(G) Anchor Bolts:

All anchor bolts shall be threaded at the top and shall conform to the plans.

Standard anchor bolts, washers, and nuts shall be fabricated from steel conforming to the strength requirements of ASTM A 36. The anchor bolts, washers, and nuts shall be fully galvanized in accordance with the requirements of ASTM A 153.

High strength anchor bolts, washers and nuts shall be fabricated from steel which meets or exceeds the minimum requirements of ASTM A 325 and shall be electro-galvanized in accordance with the requirements of ASTM B 633. Welding shall not be performed on any portion of the body of these anchor bolts. Certificates of Analysis conforming to the requirements of Subsection 106.05 shall be submitted for high strength anchor bolts, washers and nuts.

731-2.03 Wood Poles:

(A) General:

Wood poles shall consist of full length, pressure treated material. Unless specified herein, material, treatment, and preservatives shall be in accordance with the latest revisions of the AWPA Book of Standards.

No deviations from these specifications will be allowed without the written approval of the Engineer.

Wood poles shall be used for service or temporary traffic signal or roadway lighting installations when specified. The lengths of the poles shall be 25 feet for service poles and 35 feet for other poles and shall be Class 3, unless otherwise specified.

(B) Definitions:

(1) AWPA:

American Wood Preservers Association.

(2) Supplier:

The person, partnership, association, or corporation furnishing the material covered by these specifications.

(3) Check:

A separation of the wood along the grain, the greater part of which occurs across the annual growth rings. A through check extends from surface to surface of the pole, usually through the pith center.

(4) Compression Wood:

Abnormal wood that often forms on the lower side of branches and inclined trunks of coniferous trees. Characteristics include:

- (a) relatively wide annual ring, usually eccentric;
- (b) relatively high proportion of summerwood (frequently more than 50 percent of the width of the annual ring in which it occurs);
- (c) exhibits very little contrast in color between springwood and summerwood; and
- (d) shrinks excessively lengthwise as compared with normal wood.

(5) Cross-Break (Crack):

A separation of the wood cells across the grain. Such breaks may be due to internal strains resulting from unequal longitudinal shrinkage or to external force.

(6) Dead Knot:

A knot left by a branch that dies before the tree is cut. An encased knot is a dead knot in which the growth layers are not intergrown with those of the surrounding wood. Dead knots may contain soft fibers (decay) that usually do not extend deeper than one to two inches from the pole surface. They are distinct from rotten or decayed knots in which the loose or soft fibers (decay) may extend the full length of the knot into the pole, and which are frequently associated with heart rot.

(7) Dead Streak:

Any portion of sapwood in which the life processes had ended prior to the cutting of the tree. A dead streak starts from the butt and differs from a wound, such as a catface or scar, where the growth of new wood shows that life processes are still acting to repair the injured part.

(8) Decay:

Decay or rot (advanced decay) is the disintegration of wood substance due to the action of wood destroying fungi.

(9) Face of Pole:

The concave side, or the side of greatest curvature in poles having reverse or double sweep, between the ground line and top of pole.

(10) Ground Line Section:

That portion of a pole between one foot above and two feet below the ground line as defined in the pole dimension tables.

(11) Hollow Heart:

A hollow in the heartwood of a living tree caused by insects or fungi.

(12) Hollow Pith Center:

A small hole at the pith center of the trunk or of a knot, caused by disintegration of the pith (small soft core occurring in the structural center of a tree or branch).

(13) Insect Damage:

The result of boring in the pole by insects or insect larvae. Scoring or channeling of the pole surface is not classed as insect damage.

(14) Knot Diameter:

The diameter of a knot on the surface of the pole measured in a direction at right angles to the lengthwise axis of the pole.

(15) Red Heart:

A fungus caused by *Fomes Pini* occurs in the living tree, and is characterized in the early stages of infection by a reddish or brownish color in the heartwood. This is known as "firm red heart". Later, the wood, in the case of the living tree, disintegrates (decays) in small, usually distinct, areas that develop into white-line pockets.

(16) Sap Satin:

A discoloration of the sapwood caused by the action of certain molds and fungi that is not accompanied by softening or other disintegration of the wood. Refer to Subsection 731-2.03(D)(2)(a) for blue stain.

(17) Scar (Catface):

A depression in the surface of the pole resulting from a wound where healing has not re-established the normal cross section of the pole.

(18) Shake:

A separation along the grain, the greater part of which occurs between the rings of annual growth.

(19) Short Crook:

Any localized deviation from straightness, in a five-foot section or less, shall be classified as a short crook.

(20) Spiral Grain (Twist Grain):

A type of growth in which the fibers take a spiral course around the bole of a tree instead of the normal vertical course. The spiral may extend right-handed or left-handed around the tree trunk. The amount of spiral grain in a pole is measured as the distance in feet, along the axis of the pole, in which one complete twist of the spiral occurs, and is expressed as a ratio; for example, "1 in 30" (one twist in 30 feet).

(21) Split:

A lengthwise separation of the wood due to the tearing apart of the wood cells, extending from surface to surface of the pole.

(22) Sweep:

The deviation of a pole from straightness.

(C) Acceptance Species:

(1) Douglas Fir (*Pseudotsuga menziesii*, MIRB. Franco):

(2) Southern Pines:

(3) Western Pine:

- | | |
|---------------|----------------------------------|
| (a) Loblolly | (<i>Pinus taeda</i>) |
| (b) Longleaf | (<i>Pinus palustris</i>) |
| (c) Pond | (<i>Pinus rigida serotina</i>) |
| (d) Shortleaf | (<i>Pinus echinata</i>) |
| (e) Slash | (<i>Pinus caribaea</i>) |
| (f) Ponderosa | (<i>Pinus ponderosa laws</i>) |

(D) Defects:

(1) Prohibited Defects:

Pole exhibiting any of the following defects will not be accepted:

Bird Holes
Breaks

- Catface (Scars)
- Compound through checks
- Decay
- Double Sweep (poles having sweep in two planes)
- Hollow butts or tops
- Improper Framing
- Nails or other metal not authorized by the Engineer
- Plugged holes (other than increment borer)
- Small Butt
- Small Top
- Spike knots or any knot with bark inclusion
- Split top
- Worm or insect holes

(2) Limited Defects:

The following defects are acceptable subject to the limitations stated:

(a) Blue Stain:

The core used to check penetration of preservative will be checked for blue stain. Any core with 50 percent or more blue stain in sapwood will be rejected. Additional cores may be taken to determine extent of the stain.

(b) Check:

Any check more than 1/8 inch wide and extending down from the top of the pole more than 12 inches and within 30 angular degrees from the axis of the face of the pole directly above the brand will be unacceptable.

Through checks or splits in the butt surface are permitted, provided their height from the butt along the side surface does not exceed two feet.

A check is considered to be continuous if it is not separated by at least 1/2 inch of wood. Maximum acceptable dimensions of checks are as follows:

Length of Pole	Maximum Width	Maximum Length
30 feet and shorter	1/4 inch	5 feet
35 and 40 feet	5/16 inch	5 feet
45 feet and longer	3/8 inch	8 feet

(c) Compression Wood:

Compression wood in the outer 1-1/2 inch of pole.

(d) Insect damage:

Insect damage consisting of surface scoring or channeling are permitted; all other forms of insect damage are prohibited.

(e) Insufficient Sapwood:

Sapwood thickness less than the following:

Douglas Fir	1 inch
Pine	3 inches

(f) Knot:

The following criteria applies:

All knots shall be measured at right angles to lengthwise surface, including the sapwood as well as the heartwood portions. All end grained, completely concentric annual rings surrounding the prominent heartwood portion of the knot shall be included in the measurement.

The diameter of any single knot or the sum of the diameters of all knots in any one-foot section shall not exceed the limits set up in the following table. Knots 1/2 inch or less in diameter shall be ignored in applying the limitations for the sum of diameters.

Length/Class of Pole	Diameter of Any Single Knot	Sum of Diameters of Knots in Any One-Foot Section
45 feet and shorter	2.5 inches	8 inches
50 feet and longer	3.0 inches	10 inches

Maximum single knot in any sworl shall be two inches in diameter.

Maximum sum of knots in any sworl shall not exceed 20 percent of the pole circumference at the point of the sworl or more than the amount shown in the table above under the column heading "Sum of Diameters of Knots in Any One-Foot Section."

(g) Mechanical Damage:

Poles are not acceptable if they have abrasions or damage caused by forklifts, dragging along the ground, indentation of chains, cables, cant hooks, peaveys, pole tongs, or other mechanical damage penetrating the pole more than 3/4 inch.

(h) Pilodyn:

The pilodyn can be used to check hardness of poles. The test will normally be taken at the ground line and any measurement 22 millimeters and over on ponderosa pine will result in that pole being rejected. Additional tests may be taken at any point on the pole to determine extent of softness.

(i) Ring Count:

The average annual ring count shall be not less than six rings per inch average measured in the outer three inches on the butt face.

(j) Sapstain:

Stain that is not accompanied by softening or other disintegration (decay) of the wood is permitted.

(k) Shake:

Shakes in the butt surface extending through an arc of not more than 90 degrees are permitted, provided they are at least two inches from the outside diameter of butt.

(l) Short Crook:

Any localized deviation from straightness in a five-foot section or less shall be classified as a short crook, and the deviation from straightness shall not exceed 1-1/2 inches.

(m) Spiral Grain:

Spiral grain is permitted provided it does not exceed 1/2 turn in 15 feet or one complete turn in any 30 feet of the pole.

(n) Sweep:

Where sweep is in one plane and one direction only, a straight line connecting the surface of the pole at a point located six feet from the butt, and the edge of the pole at the top shall not be separated from the surface of the pole at any point by more than one inch for each 10 feet of length between these points.

Where sweep is in one plane and two directions (reverse sweep), a straight line connecting the midpoint at a point located six feet from the butt with the midpoint of the top shall not deviate from the center line of the pole more than 1/4 the diameter of the pole at the point of widest deviation.

(E) Dimensions:

(1) Length:

Poles less than 50 feet in length shall be not more than three inches shorter or six inches longer than nominal length.

Poles 50 feet or more in length shall be not more than six inches shorter or 12 inches longer than nominal length.

The minimum lengths for the wood species shown are as follows:

Wood Species	Minimum Length of Pole
Douglas Fir	50 feet
Western Pine	45 feet
Southern Pine	30 feet

(2) Classification:

The pole circumference at the top and at a point six feet from the butt shall not be less than the dimensions shown below.

Pole Dimensions, Class 3			
Minimum Circumference at Top is 23 inches		Minimum Circumference at 6 Feet from Butt (Inches)	
Length of Pole (Feet)	Groundline Distance from Butt (Feet)	Western Pine	Douglas Fir and Southern Pine (all types)
20	4	29.5	27.0
25	5	32.5	29.5
30	5.5	35.0	32.0
35	6	37.5	34.0
40	6	39.5	36.0
45	6.5	41.5	37.5
50	7	43.5	39.0
55	7.5	45.0	40.5
60	8	46.5	42.0

(F) Manufacturing Requirements:

(1) Bark Removal:

Poles shall be smoothly trimmed by machine; the depth of the cut shall be kept to a minimum consistent with proper removal of the bark. Beveling the top or butt, excessive trimming around knots which results in separation in wood structure (knot pop-up), prominent spiral ridges on pole surfaces, rough or feathery surfaces, exposed heartwood (except at knot areas), patches of inner bark more than 1/2 inch wide and six inches long, and abrupt changes in contour due to shaving are evidences of improper removal of bark. Individual poles with such defects shall be rejected.

(2) Marking:

The following marks shall be burn-branded legibly on the butt and on the face of the pole per AWP Standard M6 at a point 12 feet \pm two inches tolerance:

The supplier's code or trademark.

The Plant location and the year of treatment.

Code letters denoting pole species and preservative used.

The circumference class numeral and numerals showing the length of the pole.

(3) Treating Charge Number:

Code numerals indicating the treating charge number must be placed on the butt either by stamping or on metal tags.

(G) Preservatives:

(1) Preservative Requirements:

The type of preservative to be used shall be Penta-Volatile Petroleum Solvent (Cellon or Dow process).

(2) Penta-Volatile Petroleum Solvent:

The pentachlorophenol shall conform to AWWA Standard P8. The carriers shall be hydrocarbon solvents Type B or D conforming to AWWA Standard P9.

(H) Treatment:

(1) Poles:

Poles shall be treated in accordance to AWWA Standards C1 and C4.

(2) Moisture Content:

Prior to treatment, poles shall be sufficiently air-seasoned, bouldonized or kiln-dried to minimize checking after treatment and to permit maximum penetration and retention of preservative. Moisture content of the sapwood shall be below 25 percent. The moisture content may be determined by electrical resistance type moisture meters and shall have insulated needles driven two inches in fir or 2-1/2 inches in pine.

(3) Retention:

Douglas Fir - The treating process must produce not less than one inch penetration at any point on the pole. If the sapwood thickness exceeds one inch between the butt and standard ground line, 85 percent of the sapwood shall be treated. The assay zone shall be 1/4 to one inch.

Cellon or Dow Process - Retention shall be not less than 0.90 pounds per cubic foot in the assay zone.

Western and Southern Pines - The treating process must produce complete sapwood penetration. The assay zone shall be 0.5 to 2.0 inches.

Cellon or Dow Process - Retention shall be not less than 0.60 pounds per cubic foot in the assay zone.

(4) Penetration:

Not less than one increment core shall be taken in the ground line area. All increment borer holes shall be plugged with tight fitting cylindrical wood plugs treated with the same preservative used to treat the pole. Penetration shall be determined by the following methods.

Cellon or Dow Process - Penta Check or Wetzal Stain.

(5) Cleanliness - After Treatment:

Cellon or Dow Process - Poles shall be washed or brushed so they are clean and free of surface crystals.

(6) Retreatment:

All poles which fail to meet the treating requirements of this specification may be treated one time after initial inspection. Temperature and pressure must conform to AWP Standard C1 for retreatment.

Stored Poles - All poles showing brands or marks indicating treatment within any calendar year three years or more previous to the year of shipment shall be retreated one time conforming to AWP Standard C1.

Cut Back Poles - All poles that are shortened or trimmed shall be retreated within seven days conforming to AWP Standard C1.

(I) Inspection:

Inspection shall be made upon delivery. The Contractor shall provide the necessary assistance and facilities to enable safe and efficient inspection of the work. A Certificate of Compliance shall be furnished to the Engineer upon delivery to the job site or other approved locations.

731-2.04 Mast Arms and Tie Rods:

Mast arms for standard steel poles that are not tapered shall be fabricated from steel pipe as specified in ASTM A 53. The arms shall conform to the dimensions shown on the Standard Drawings. The pipe shall be one piece and free from burrs.

Tapered mast arms shall be fabricated from sheet steel conforming to the requirements of ASTM A 36, except for the types K and R pole mast arms. The mast arms for the types K

and R poles shall be constructed of sheet steel with a minimum yield stress of 48,000 pounds per square inch after fabrication. Mast arms shall be fabricated according to the thickness requirements shown on the plans. A taper rate of 0.14 inches change in diameter per linear foot shall be required unless otherwise specified. All bolts, washers, and nuts for mast arms shall be fabricated from steel conforming to the requirements of ASTM A 325 and shall be electro-galvanized in accordance with the requirements of ASTM B 633.

Mast arms shall be bent to the dimensions and curvature shown on the plans.

Tie rods shall be fabricated from weldable structural steel pipe and steel rod and shall have no kinks or bends. All dimensions of the tie rods shall be as specified in the plans, except that the mast arms and tie rods for wood pole installations shall conform to the details shown on the project plans.

Mast arms and tie rods shall be galvanized in accordance with the requirements of ASTM A 123. The visual appearance of the galvanized finish shall be uniform. Discoloration of the galvanized finish such as dark areas, dark streaks, dark rings or transportation handling marks which are considered excessive by the Engineer shall not be allowed. Mast arms and tie rods that have a finish unacceptable to the Engineer shall either be repaired or replaced to the satisfaction of the Engineer at no additional cost to the Department.

A metal tag shall be permanently attached on the side of the mast arm near the base stating the manufacturer's name, pole type as required on the plans, mast arm or pole drawing number, length, and gage number.

731-3 Construction Requirements:

731-3.01 Foundations:

The excavations required for the installation of foundations and other items shall be performed in such a manner as to avoid any unnecessary damage to streets, sidewalks, landscaping, and other improvements. The trenches shall not be excavated wider than necessary for the proper construction of the foundations and other equipment. Excavation shall not be performed until immediately before construction of foundations. The material from the excavation shall be placed in a position that will minimize obstructions to traffic and interference with surface drainage.

All surplus excavated material shall be removed and properly disposed of within 48 hours by the contractor, as directed by the Engineer. After each excavation is completed, the contractor shall notify the Engineer for inspection, and under no circumstances shall any underground materials or equipment be covered with fill without the approval of the Engineer.

Excavation and backfill shall be in accordance with the requirements of Subsection 203-5. At the end of each working period, all excavations shall be barricaded or covered, or both, to provide safe passage for pedestrian and vehicular traffic.

Excavations in the street or highway shall be performed in such a manner that not more than one traffic lane is restricted at any time, unless otherwise provided in the Special Provisions.

Sidewalk and pavement excavations shall be kept well covered and protected to provide safe passage for pedestrian and vehicular traffic until permanent repairs are made.

Signal and lighting pole foundations shall be set flush with the existing or new curb and sidewalk or flush with the finished grade where there is no curb or sidewalk, except in sloped areas they shall be as shown on the project plans. The dimensions and locations of foundations shall be as specified on the project plans; however, the Engineer may direct that changes be made in locations due to obstructions or other existing conditions. The contractor shall verify top of foundation elevations with the Engineer prior to foundation construction.

Concrete shall be placed in holes which have been augered against undisturbed earth. If the material in the bottom of the hole is not firm and stable, it shall be compacted or treated as directed by the Engineer. The walls and the bottoms of the holes shall be thoroughly moistened prior to placing the concrete.

If the soil is not stable and a hole cannot be augered, forms shall be used. They shall be of the proper size and dimensions and shall be rigid and securely braced. The forms and the bottoms of the holes shall be thoroughly moistened prior to placing the concrete.

If the Engineer requires foundations to be larger or deeper than on the plans because of soil conditions, the additional work will be paid for in accordance with the provisions of Subsection 109.04.

Anchor bolts and conduit stubs shall be placed and held in proper alignment, position, and height during the placing and vibrating of concrete. All pole foundations shall set for three days prior to pole installation except for types J, K, Q and R pole foundations which shall set for seven days.

Before the concrete for cabinet foundations has set, depressions shall be made around the anchor bolts for adjustment of the cabinet leveling nuts.

731-3.02 Base Plates and Poles:

High strength bolts, nuts, and washers for slip-away bases shall be assembled as specified in the Standard Drawings and shall be torqued as required by the Standard Drawings. Anchor bolts, washers, and nuts required for relocating existing poles shall be furnished by the contractor.

Poles shall be drilled and tapped for mounting hardware as shown on the Standard Drawings. Use of through bolts will not be permitted. Poles will be rejected if holes are not properly positioned for the required mounts.

All steel poles shall be plumbed to the vertical with all mast arms, signal heads and luminaires installed.

Sidewalks, curbs, gutters, pavement, base material, lawns, plants, and any other improvements removed, broken, or damaged by the contractor's operations shall be replaced or reconstructed with materials in accordance with these specifications. The replaced or reconstructed improvements shall be left in a serviceable condition satisfactory to the Engineer, and shall conform to these specifications where applicable.

Where existing pole installations are to be modified, materials and equipment shall be used, salvaged, or disposed of as specified in the Special Provisions and as directed by the Engineer.

Wood poles shall be placed in the ground to a depth of at least six feet. After each wood pole is set in the ground, the pole shall be backfilled with selected backfill. Backfill shall be free of large rocks and debris, and placed in layers of no more than six inches before compaction. Each layer shall be moistened and thoroughly compacted to the satisfaction of the Engineer.

Existing poles shall be either relocated or used in place as specified in the project plans. The contractor shall inspect the poles and provide the materials and work necessary to recondition the poles so they can be reused. Holes left in the shafts of existing poles, due to removal of items such as signal mounting assemblies, shall be repaired and painted with a zinc galvanized paint.

If any poles are damaged by the contractor's operations, such repairs or replacements shall be at no additional cost to the Department. If the Engineer orders additional work to be done following the contractor's inspection of the poles, such work will be paid for as provided in Subsection 109.04.

New poles that are damaged by improper drilling of holes will be rejected.

731-3.03 Removing and Replacing Improvements:

Wherever a part of a section or slab of existing concrete or sidewalk or curb is damaged by the contractor, the entire section between expansion joints shall be removed and the concrete reconstructed as directed by the Engineer.

All areas of concrete sidewalks and driveways and all areas of Portland cement concrete and asphaltic concrete pavements to be removed shall be outlined and cut to a minimum depth of 1-1/2 inches with an abrasive type saw prior to removing the material. The cut for the remainder of the required depth may be made by any method satisfactory to the Engineer. Saw cuts shall be neat and true with no shattering or chipping of concrete adjacent to the outside of the removal area.

731-4 Method of Measurement:

The structural supports and foundations for traffic signals and highway lighting will be measured as a unit for each type of support and foundation furnished and installed.

Modification of existing poles and mast arms will be measured as a unit for each pole or mast arm modified.

731-5 Basis of Payment:

The accepted quantities of supports and foundations for signals and lighting, measured as provided above, will be paid for at the contract unit price each, for the type of support or foundation designated in the bidding schedule, complete in place, which price shall be full compensation for the work described and specified herein and on the plans, including all hardware, wire, excavation, backfill and incidentals necessary to complete the work.

The accepted quantities of modify pole and modify mast arm, measured as provided above, will be paid for at the contract unit price each, for the type of pole or mast arm designated in the bidding schedule to be modified, which price shall be full compensation for the work described and specified herein and on the plans, including all parts, hardware and incidentals necessary to complete the work.

No measurement or direct payment will be made for anchor bolts, the cost being considered as included in the unit price paid for foundations.

SECTION 732 ELECTRICAL UNDERGROUND MATERIAL:

732-1 Description:

The work under this section shall consist of furnishing and installing electrical conduit, conductors, and pull boxes for traffic signals and highway lighting including jacking, drilling, excavating, backfilling, and compacting at the locations designated on the project plans and in accordance with the details shown on the plans and the requirements of these specifications.

732-2 Materials:

732-2.01 Electrical Conductors:

Electrical conductors shall be stranded or single conductor, thermoplastic insulated electrical wire or cable. Conductors shall conform to the specifications of the NEC, UL, and other applicable industry standards.

Wire and cable for traffic signal, highway lighting and other electrical systems shall be UL listed and rated for 600-volt operation. The UL label shall be present on each reel, coil or container of wire or cable. When requested, the contractor shall submit to the Engineer the manufacturer's written certification that the product conforms to the requirements of these specifications.

All single conductors, except detector lead-in cables, shall have plain, distinctive and permanent markings on the outer surface throughout the entire length showing the manufacturer's name or trademark, insulation type letter designation, conductor size, voltage rating and the number of conductors in the cable.

The wire shall be annealed copper and shall be uncoated unless otherwise specified. The wire shall be solid for number 10 AWG and smaller, conforming to the requirements of ASTM B 3 for annealed bare copper wire. Conductors for sizes number 8 AWG and larger shall be stranded and shall conform to ASTM B 8 for Class B stranding. Unless otherwise specified, the conductors shall be insulated with THW grade thermoplastic compound and shall meet the requirements of UL 83. Insulation colors shall be permanent and an integral part of the insulation and shall not be applied as a surface treatment or coating. The insulation thickness shall conform to the requirements of the NEC. Conductor insulation shall be a solid color as specified in the conductor table unless otherwise specified. The color shall be continuous over the entire length of the conductor.

(A) Traffic Signal and Highway Lighting Conductors:

Conductors used for traffic signal and highway lighting systems shall conform to the requirements of the following table. The minimum conductor sizes shall be as shown in the following table unless otherwise specified.

CONDUCTOR TABLE						
CIRCUIT	SIGNAL PHASE OR FUNCTION	INSULATION		CONDUCTOR		
		COLOR	TYPE	Minimum Thick. (MILS)	Minimum Gauge (AWG)	TYPE
Vehicle Signals	Red Interval	Red	THW	45	12	
	Yellow Interval	Yellow	THW	45	12	
	Green Interval	Green	THW	45	12	
Pedestrian Signals	Intl. Symbol Hand/Man	Red	THW	45	12	
		Green	THW	45	12	
Pedestrian Push- Button	Pedestrian Detection	Orange	THW	45	12	
Series Lighting	Series Loop	Black	THW 5 kv	150	8	S
Highway Lighting	Multiple Lighting	Black	THW	45	12	
Lighting in Pole	Pull box to Luminaire	Black	XHHW	30	12	S
Sign Lighting	Multiple Lighting	Black	THW	45	12	
Common	Common Lead	White	THW	45/60	12/8	
Spares	Unused Leads	Brown or Black	THW	45	12	
Detection	Detector Roadway Loops	Black	THWN	15	14	S
		Orange	in PVC	31		

CONDUCTOR TABLE						
CIRCUIT	SIGNAL PHASE OR FUNCTION	INSULATION		CONDUCTOR		
		COLOR	TYPE	Minimum Thick. (MILS)	Minimum Gauge (AWG)	TYPE
			Tubing			
Detection	Loop Detector Lead in Cable	Clear Black	PE Foil Shield Vinyl	32	14/16/18	STP
Detection	Magnetometer Lead in Cable	Red Black Green White	PE in PVC Jacket	18 18 18 18	18 18 18 18	S4C
	Service Service Common Bond	Black White Green or Bare	THW THW	AS AS AS	AS AS 8	
Legend: AS = As Specified; PE = Polyethylene; S = Stranded; STP = Stranded, twisted pair; S4C = Stranded, 4 Conductor						

(1) Roadway Loop Detector Wire:

Roadway loop detector wire shall be a factory assembled combination of PVC tubing and wire. Loop detector wire shall be stranded number 14 AWG copper, rated at 600 volts with THWN insulation. The wire shall be enclosed in a factory extruded PVC flexible tubing by the wire manufacturer. Contractor assembly of the wire in the flexible tubing will not be acceptable.

The PVC tubing shall be UL FR-1 rated at 105 °C and have a moisture absorption of less than one percent. The wall thickness shall be 31 ± 3 mils with a nominal inner diameter of 0.186 inches. The tubing shall be orange in color, be highly resistant to chemicals and oils, and have a dielectric strength of 900 volts per centimeter.

(2) Wire Marking Tags:

Wire marking tags shall be made of flame retardant reinforced epoxy tape 5.5 mils in thickness and 1/4 inch minimum width. The tape shall be flexible, resistant to oil and water, and have a pressure sensitive acrylic adhesive backing. The adhesive shall be a high tack adhesive with good adhesion to clean neoprene, hypalon, nylon and PVC insulation materials. The film material shall conform to the flame retardant requirements of UL 510 and be rated at 150 °C. Appropriate numbers and letters shall be printed on wire tags for conductor identification.

(B) Cable:

(1) Shielded Cable:

Shielded cable used for loop detector lead-in cable and telephone coordination interconnect circuits shall be two-conductor, stranded, twisted pair, aluminum-polyester foil shield with 100 percent coverage, tinned copper with polyethylene insulation, vinyl jacketed, rated at 600 volts and 60 °C, and shall be in conformance with UL and the following table:

TABLE FOR SHIELDED CABLE		
AWG Size Number	14	16
Stranding	19 x 27	19 x 29
Insulation Thickness, inches	0.032	0.032
Jacket Thickness, inches	0.035	0.032
Outside Diameter, inches	0.340	0.274
Ground Wire AWG Number	16	18
Nominal Capacitance* (pF/ft)	24	24
Nominal Capacitance** (pF/ft)	47	47
* Capacitance between conductors.		
** Capacitance between one conductor and another conductor connected to the shield.		

(2) Instrumentation Cable:

Instrumentation cable normally used for magnetometer detectors shall be a number 20 AWG four-conductor, low-capacitance cable suitable for both conduit and direct burial.

The cable shall be round and be less than 0.25 inches in overall diameter. The jacket shall be a weatherproof, high density, heavy duty, abrasion resistant, polyethylene material with a minimum thickness of 0.032 inches.

The cable shall have an interior moisture penetration barrier to prevent capillary absorption of water and be suitable for a temperature range of -60 °C to +80 °C.

Each conductor shall have thermoplastic insulation with a minimum thickness of 0.018 inches. The conductor to conductor capacitance shall not be greater than 18 picofarads per foot for adjacent pairs and 15 picofarads per foot for diagonal pairs with all other conductors disconnected.

(3) IMSA Cable:

IMSA cable shall be used only when specified on the plans. IMSA signal cables shall be polyethylene insulated copper conductors, polyvinyl chloride jacketed, rated at 600 volts for use in underground conduit or as aerial cable conforming to International Municipal Signal Association Specification No. 19-1.

The IMSA-19 cable shall be provided with the number and size of conductors as specified on the plans. The cable shall use the standard IMSA colors for conductor insulation. The colors and tracers shall be permanent and an integral part of the insulation, and shall not be painted, surface coated, or adhered to surface.

732-2.02 Electrical Conduit and Warning Tape:

All conduit and fittings shall be listed by UL, and conform to NEC standards. Except as specified below, all conduit to be installed underground or in concrete structures shall be rigid Polyvinyl Chloride (PVC) non-metallic type conforming to the requirements of UL 651 for Rigid Non-Metallic Conduit. PVC conduit and fittings shall be Schedule 40, heavy wall, manufactured from high impact material and shall be rated for use at 90 °C.

All exposed conduit and fittings to be installed above ground shall be the rigid metal type manufactured of galvanized steel conforming to requirements of UL 6 for Rigid Metallic Conduit. Non-threaded couplings shall not be used. Rigid metal galvanized steel conduit bends shall be used for entering pull boxes that are spaced more than 150 feet apart.

Intermediate metal conduit may be used in place of rigid metal conduit except for service risers. Galvanized intermediate metal conduit shall conform to the requirements of UL 1242. Intermediate metal conduit and fittings shall be manufactured from steel and work hardened to provide high strength. The exterior wall shall be hot-dip galvanized. Threads shall be fully cut and galvanized after cutting. All threaded fittings shall be the same as fittings approved for metal conduit.

Flexible conduit shall be a liquid-tight flexible metal type and shall be used as specified. The conduit shall be a flexible galvanized steel core over which is extruded a PVC cover. Approved liquid-tight fittings shall be furnished and installed with the conduit.

Sampling and testing procedures shall conform to UL Standards. Samples for testing, when requested by the Engineer, shall be furnished at no additional cost to the Department. Samples of conduit shall be tested by UL standards and be approved for use by the Engineer prior to installation on the project.

Conduit warning tape shall be a four-mil inert plastic film specially formulated for prolonged use underground. All tape shall be highly resistant to alkalis, acids, and other destructive agents found in the soil.

Tape shall have a continuous printed message warning of the location of underground conduits. The message shall be in permanent ink specifically formulated for prolonged underground use and shall bear the words, "CAUTION - ELECTRIC LINE BURIED BELOW" in black letters on a red background.

732-2.03 Pull Boxes:

Precast reinforced concrete pull boxes, covers and extensions shall be installed and located as shown on the project plans and shall be the size specified.

Chipped or cracked pull boxes, covers, and extensions will not be accepted.

Portland cement concrete shall conform to the requirements of Section 1006 for Class B concrete. When requested by the Engineer, pull boxes, covers, and extensions shall be furnished for testing at no additional cost to the Department.

Covers shall be marked as follows:

“A.D.O.T. ELECTRICAL HIGH VOLTAGE”

Markings shall be clearly defined and uniform in depth and shall be placed parallel to the long side of the cover. Letters shall be one inch high.

732-2.04 Metal Junction Boxes:

Metal junction boxes and covers for installation in concrete structures shall be fabricated from a minimum of 16 gage type 304 stainless steel. All seams shall be continuously welded and shall conform to the dimensions and details shown on the project plans. A neoprene gasket with a thickness of 1/8 inch shall fit between the box and the cover. The cover shall be made to fit securely and shall be held in place with a minimum of four stainless steel machine screws. Tabs for ease of installation may be attached to the junction box at the option of the contractor.

732-3 Construction Requirements:

732-3.01 Installation of Electrical Conduit and Pull Boxes:

Conduit runs shown on the project plans shall be changed to avoid underground obstructions as directed by the Engineer.

The contractor may, at its option and at no additional cost to the Department, use a larger size conduit than specified provided the larger size is continuous for the entire length of the run from outlet to outlet. Reducing couplings will not be permitted. Changes in the location and size shown on the project plans shall be documented by the contractor and submitted to the Engineer.

The PVC conduit shall be cut square and trimmed to remove all rough edges. Conduit connections shall be of the solvent weld type. Purple primer conforming to the requirements of ASTM F 656 shall be applied to the joined surfaces prior to use of cement. The joint cement shall be the gray PVC cement conforming to the requirements of ASTM D 2564. Where a connection is made to steel conduit, the coupling used shall be a PVC female adapter.

Expansion fittings shall not be installed in PVC conduit runs between two pull boxes unless otherwise specified. Expansion fittings shall be installed in conduit runs in which both ends of the conduit are fixed in place such as between two foundations. Expansion fittings shall be installed in conduit runs which cross any expansion joint in a concrete structure. Approved expansion fittings shall allow for a linear thermal expansion of up to six inches.

If a trench has to be left open overnight, a minimum of six inches of backfill material shall be used as a protective cover to eliminate contraction of the conduit system. The backfill material shall be removed if final inspection by the Engineer has not been made.

Backfill containing large rock, paving materials, cinders, large or sharply angular substance, or corrosive material, shall not be placed in an excavation where materials may damage raceways, cable, or other substructures or prevent adequate compaction of fill or contribute to corrosion of raceways, cables or other substructures.

Where necessary to prevent physical damage to the raceway or cable, protection shall be provided in the form of granular or selected material, suitable running boards, suitable sleeves, or other approved means.

Excavation and backfill shall be in accordance with the requirements of Subsection 203-5.

All PVC conduit shall be stored and handled in an approved manner to minimize ultraviolet deterioration due to exposure to sunlight.

Conduits in protected areas such as behind curbs, in sidewalks, etc., that are not subject to any vehicular traffic shall be at a minimum depth of 18 inches. Conduits installed under roadways, driveways or any open areas where it is possible for vehicles to drive and conduits with conductors that have voltages over 250 volts, shall be at a minimum depth of 30 inches. When conduit in protected and open areas cannot be installed at the minimum depths, it shall be encased in concrete.

Where specified due to shallow trenching depths, the conduit shall be encased in a minimum of three inches of concrete. The conduit shall be supported with masonry block or brick on 10-foot centers, during encasement, so that the conduit will be completely encased.

Installation of conduit for underground primary service shall conform to the utility company requirements, local codes and the Special Provisions. Conduit installed in railroad right-of-way shall be to the depth specified by the railroad company.

Except for factory bends, conduit bends shall have a radius of not less than that specified in the NEC. Conduit shall be bent without crimping or flattening, using the longest radius practicable.

Existing underground conduit to be incorporated into a new system shall be cleaned and blown out with compressed air.

Conduit for future use shall have a number 8 AWG bare bond wire installed with at least two feet of pull wire doubled back into the conduit and capped.

A three-inch "Y" shall be cut into the face of the curb directly over conduit located under curbs.

The contractor shall place warning tape in all trenches in which new conduit is placed. All warning tape shall be buried at a depth of six to eight inches below the finished grade.

Conduit entering pull boxes shall terminate a minimum of three inches inside the box wall. The conduit shall be between two and four inches above the bottom of the pull box and

shall be sloped to facilitate pulling of conductors. Conduit entering through the bottom of a pull box shall be located near the sides and ends in order to leave the major interior portion clear. At all outlets, conduits shall enter from the direction of the run and allow for expansion and contraction.

Rigid metal conduit bends shall be used for entering pull boxes that are spaced more than 150 feet apart. The bends shall be 90 degrees and be of the same diameter as the connecting conduit. The bends shall be wrapped with an approved PVC tape.

Conduit ends shall be capped with conduit end cap fittings until wiring is started. When end caps are removed, PVC ends shall be provided with an approved conduit end bell. End bells shall be installed prior to the installation of the conductors. Approved insulated grounding bushings shall be used on steel conduit ends.

Conduit embedded in concrete structures shall be securely attached to the reinforcing steel at intervals of approximately 12 inches. Expansion fittings shall be installed where conduit crosses expansion joints in the structure. Where bonding is not continuous, expansion fittings shall be provided with a bonding jumper of number 6 AWG flexible wire. Where it is not possible to use expansion fittings, sleeves of sufficient size shall be installed to provide a minimum 1/2-inch clearance between the conduit and the inside wall of the sleeve. The sleeve shall be discontinuous at the expansion joints.

All existing conduits and conduit embedded in concrete structures shall be cleaned out with a mandrel and blown out with compressed air.

Conduit shall be installed under existing pavement by jacking or drilling methods approved by the Engineer. Open trench excavation across an existing roadway shall not be permitted without the written permission of the Engineer. Jacking and drilling pits shall be kept two feet clear of the edge of the pavement. Pull boxes shall be installed in accordance with the details shown on the project plans and the standard drawings. Pull boxes shall be installed flush with the finished grade and when in concrete shall have a 1/2-inch felt expansion joint installed around all sides of the pull box. Junction boxes placed in concrete structures shall be flush with the finished concrete surface.

732-3.02 Wiring Procedures:

(A) General:

Wiring shall conform to the regulations and codes listed in Subsection 730-3, and of the NEC, and shall be UL listed and bear the UL labels and the following requirements:

The conductors shall be pulled into runs in a smooth continuous manner, avoiding contact with sharp objects that might damage the insulation. Approved lubricants shall be used for inserting conductors in conduit. Before installation, conductor ends shall be taped for moisture protection until connections are made.

Conductors shall have a minimum of 36 inches of slack from the conduit end bell in the pull box.

All ungrounded ballast primary leads shall be protected with fused in-line connectors. Unfused in-line connectors shall be installed on all ballast secondary leads. In-line connectors shall be fused with fast-acting, high-interrupting capacity fuses with a fault current rating of 100 kiloamperes at 600 volts AC. The in-line connectors shall be watertight, non-locking and rated at 600 volts AC.

(B) Splices:

In circuits where the voltage does not exceed 600 volts AC, splices shall be made utilizing approved spring-type wire connectors. Soldered connections will not be permitted unless so specified. The insulation for the splice shall consist of two layers of electrical rubber tape, four layers of plastic electrical tape and two layers of friction tape. The tapes shall be securely applied over the bare wire splice area and back onto the original insulation a minimum of one inch. A minimum of three coats of approved liquid waterproof splicing compound shall then be applied to the splice. The finished splices shall be such that their electrical and mechanical characteristics and insulation quality are equal to those of the original cable. Conductors shall be spliced only in pull boxes, terminal compartments, pedestals, or cabinets.

Splices for high-voltage series lighting conductors shall be made from an approved splice kit. The splices shall consist of either molded rubber plug-in connectors or epoxy resin mold type splice insulating kits and shall be rated at five kilovolts. The finished splice shall make a sealed waterproof connection which shall be equal to the original cable conductors and insulation.

Cable used for detector lead-in and telephone interconnect circuits shall be run continuous and unspliced to the controller cabinet. Unless otherwise shown on the plans, one lead-in cable shall be installed per loop detector except for six foot by six foot loop detectors.

Signal circuit conductors for each mast arm mounted signal assembly shall be continuous without splicing from the pull box, adjacent to the pole, to the terminal blocks in the mast arm assembly.

(C) Tagging:

All conductors shall be tagged to identify their circuit number or function with wire marking tags. The tag identification shall correlate with the conductor schedule shown on the project plans. The tags shall be furnished and installed by the contractor. Each tag shall be wrapped entirely around the conductor twice. Each signal wire shall be tagged as to phase, color indication, and function such as vehicle indication, pedestrian indication, or pedestrian push button (Phase 1 - Red, Yellow, Green, etc). Each phase group shall also be tied together and tagged. Each lighting circuit wire shall be tagged to identify the circuit number and other types of circuits. Black wires used as spares shall be tagged as spares.

(D) Testing:

(1) Signal Circuits:

Prior to control cabinet installation, the contractor shall apply 120 volts to signal circuits and verify equipment is operational. The Department will connect field wiring inside the control cabinet.

(2) Roadway Lighting Circuits:

The contractor shall connect field wiring to the load center terminals. Lighting circuits shall be energized for 100 hours as directed by the Engineer prior to final acceptance. Failures occurring during this test period shall be corrected.

Wires shall be tagged in control cabinets, load center cabinets, pull boxes, terminal compartments of signal mounting assemblies, or wherever splicing occurs.

732-3.03 Bonding and Grounding:

All metallic enclosures such as cabinets, pedestals, poles, conduit and cable sheaths shall be bonded to form a continuous grounded system. Non-metallic portions of the system such as PVC conduit shall have a bare copper bond wire or a green insulated copper bond wire installed with suitable connections to form a continuous grounded system. In all traffic signal conduits, the copper bond wire shall have green insulation. The insulation shall be removed from the bond wire in pull boxes from the point at which the wire leaves the bell end of the conduit.

At each service disconnect, cabinet foundation, or where otherwise specified, an approved copper-plated ground rod shall be installed. Each ground rod shall be a one-piece solid rod of the copper weld type or approved equal and shall be a minimum of 5/8 inch in diameter and 10 feet in length. The rod shall be driven vertically into the ground to a minimum of nine feet below the surface. The ground rod may be located in a pull box. The service equipment neutral and the system grounding bond shall be connected to the ground rod with a copper-plated bolt or a brass bolt on the ground clamp.

Pole foundations shall have 25 feet of number 4 AWG bare copper conductor coiled and placed at the bottom of the excavation before concrete is poured. The conductor shall be connected to the pole grounding screw in the hand hole with an approved lug connector.

A ground resistance test shall be performed for each installed ground rod prior to final connection of the utility service. Pole foundation coil grounds shall be tested as determined by the Engineer in the field.

The ground resistance shall be measured with a three-terminal, fall of potential, direct reading, battery-powered earth tester with a 0.50- to 500-ohm scale or digital read-out. The 25-ohm reading shall be approximately at mid scale.

The test shall be performed according to the manufacturer's instructions and OSHA requirements. Two auxiliary copper clad ground rods shall be driven into the ground a minimum of three feet. The lateral spacing for each test rod shall be given in writing on the test report form and the spacing shall be approved by the Engineer.

All tests shall be performed in the presence of the Engineer and test results shall be written down, dated, and given to the Engineer for approval.

Each ground rod or foundation ground shall be isolated with the bond wires disconnected when the test is being performed. The resistance to ground shall be 25 ohms or less. If it is not, additional ground rods shall be installed as required at least 15 feet from the original ground and shall be bonded to it. The test shall then be repeated for multiple grounds as necessary to achieve proper grounding below 25 ohms. As many additional ground rods shall be installed as is necessary to achieve proper grounding of 25 ohms or less.

The test shall be performed when the soil is dry. The contractor shall not add any chemical, or salt solutions to any portion of the grounding system. All grounding rods and foundation grounds to be tested shall be installed a minimum of 10 days prior to testing unless otherwise determined by the Engineer in the field.

732-3.04 Service:

Service system components and their installation shall conform to regulations and codes listed in Subsection 730-3, NEC, UL, local applicable codes, and the requirements of the utility company providing service.

Service risers shall be PVC-mold or galvanized steel as specified. Fastening of the service risers shall be done through the use of suitable straps and wood screws a minimum of 1-1/2 inches in length. Tape, nails or other means of attachment shall not be used.

Plywood backing boards, when required, shall be 3/4-inch, medium density, paper faced and of an appropriate size to mount all the necessary components. An approved primer and two finish coats of light gray paint, conforming to Section 1002, and acceptable to the Engineer, shall be applied to the plywood before the components are mounted. Special care shall be taken to insure that the edges are well sealed.

All safety switch and multi-breaker enclosures shall be provided with a padlock to prevent unauthorized persons from operating equipment of disconnects. Padlocks will be furnished by the Department.

Meter sockets, when required, shall be approved by the serving utility company. They shall be furnished and installed by the contractor. The meter socket shall be located as shown on the project plans. Meter service inspection shall be approved by the Engineer prior to service connection by the utility company.

If work is required on existing high voltage and series lighting circuits, the contractor shall obtain daily safety circuit clearance from the Department and the serving utility company prior to any work being done.

Signs painted "Danger-High Voltage" and "Arizona Department of Transportation" shall be installed permanently by the contractor on all Department electrical service structures. These signs will be furnished by the Department.

Fused cutouts on the voltage side of a series lighting service structure shall be pulled out and safety signs shall be furnished by the contractor and posted on the cutouts before any work is done. The signs shall be painted "Danger-High Voltage" and shall give the name of the company doing the work.

732-4 Method of Measurement:

Conductors (for lighting) will be measured by the linear foot for each gage size as follows:

- (1) From center to center of pull boxes.
- (2) From edge of foundation to center of pull box.
- (3) From edge to edge of foundation.
- (4) From end of conduit to center of pull box.
- (5) From end to end of conduit when no pull boxes are used.

Conductors (for signals and lighting) will be measured as a complete unit of work. This method of measurement shall be used for signal and lighting conductors shown in the signal conductor schedule on the project plans.

No measurement or direct payment will be made for conductors in poles and pull boxes, the cost being considered as included in the contract price for the pole and pull box items.

Conduit will be measured by the linear foot for each diameter size as follows:

- (1) From center to center of pull boxes.
- (2) From edge of foundation to center of pull box.
- (3) From edge to edge of foundation.
- (4) From end of conduit to center of pull box or foundation.
- (5) From end to end of conduit when no pull boxes are used.

Pull boxes will be measured as a unit for each pull box.

732-5 Basis of Payment:

732-5.01 Conductors (for lighting):

The accepted quantities of conductors (for lighting), measured as provided above, will be paid for at the contract unit price per linear foot, which price shall be full compensation for the item, complete in place.

732-5.02 Conductors (for signals and lighting):

Conductors (for signals and lighting), measured as provided above, will be paid for at the contract lump sum price, which price shall be full compensation for the work, complete in place.

732-5.03 Conduit:

The accepted quantities of conduit, measured as provided above, will be paid for at the contract unit price per linear foot, which price shall be full compensation for the work, complete in place, including excavation, backfill and any incidentals necessary to complete the work. No direct payment will be made for rigid metal conduit bends or rigid non-metallic conduit bends at pull boxes, expansion fittings and coupling fittings, the cost being considered as included in the contract price for the conduit items.

732-5.04 Pull Boxes:

The accepted quantities for pull boxes, measured as provided above, will be paid for at the contract unit price each, which price shall be full compensation for the work, complete in place, including any excavating and backfilling necessary to complete the work.

SECTION 733 SIGNAL INDICATIONS AND MOUNTING ASSEMBLIES

733-1 Description:

The work under this section shall consist of furnishing and installing or modifying traffic signal indication assemblies, pedestrian signal indications, flashing beacons, and mounting assemblies at the locations shown on the project plans and in accordance with the details shown on the plans and the requirements of these specifications.

733-2 Materials:

733-2.01 Signal Indications:

All new signals, except the programmed visibility and the pedestrian types, installed at any one intersection shall be of the same manufacturer and of the same material.

All traffic signal indication housings, pedestrian, indication, housing backplates, visors, louvers, mounting assemblies, and push button stations, shall receive a minimum of two coats of dull black enamel. Painting shall be done by the manufacturer.

(A) Standard Signal Faces:

Each vehicle signal face shall be of the adjustable vertical type with the number and type of sections specified on the plans.

Adjustment shall permit rotation of 360 degrees about a vertical axis. Each vehicle signal face shall provide an indication in one direction only.

Unless otherwise shown on the plans, all vehicle signal faces shall contain three sections arranged vertically; red-top, yellow-center, green-bottom.

Signal faces shall be standard eight-inch or 12-inch lens size.

(1) Optical Equipment:

Each optical unit shall consist of a lens, a reflector or reflector assembly, a lamp holder, and a clear traffic signal lamp of the appropriate size and type as specified herein or in the Special Provisions. The optical units shall conform to ITE Standards and ANSI Standard D 10.1.

(a) Lenses:

All traffic signal face lenses shall be glass unless otherwise specified on the plans.

Lenses shall be of the color indicated, circular in shape, with a nominal visible diameter as indicated on the project plans and of such design as to give an outward and downward distribution of light with a minimum above the horizontal. Each lens shall be true to color, of the best quality glass, free from imperfections, and provide high illumination transmission. Lenses shall conform to ITE Standards.

(b) Reflectors:

Each reflector shall be a single piece of silvered glass or specular aluminum with an anodic coating. Reflectors shall conform to ITE Standards. An opening in the back of the reflector for the lamp holder shall be constructed so that there will be no dark spots cast on the lens.

(c) Lamp Holders:

The lamp holder shall have a heat-resistant molded phenolic housing and be designed to accommodate up to a 150-watt standard A-21 traffic signal lamp, in the proper focal position.

(d) Lamps:

Lamps to be used in vehicular traffic signal faces shall conform to the standards set forth in the ITE publication "Standard for Traffic Signal Lamps" and the following table, unless otherwise specified:

TRAFFIC SIGNAL LAMP TABLE						
Nominal Size	Bulb Type	Lens Color	Initial Lumens	User-Hours	Rated Wattage	Light Center Length
8 inch	A19	Green Yellow	610	8000	60	2-7/16 inch

TRAFFIC SIGNAL LAMP TABLE						
Nominal Size	Bulb Type	Lens Color	Initial Lumens	User-Hours	Rated Wattage	Light Center Length
8 inch	A19	Red	1040	8000	90	2-7/16 inch
12 inch	A 21	Green Yellow Red	1750	8000	135	3 inch
Pedestrian Indication	A 21	White Orange	1750	8000	135	3 inch

All lamps shall be rated at 120 volts AC.

Lamps shall be clear and have an aluminum reflector disc. Projection type filaments shall be used, and supported at seven points. Name of manufacturer, wattage, voltage, and user-hours shall be etched on lamps. Amount of krypton gas shall be not less than 80 percent of the total fill gas of the lamp. If requested by the Engineer, the lamp manufacturer shall provide a report by an independent testing laboratory certifying the beam candle power and composition of the fill gas.

(2) Hardware:

Hardware for a standard signal section shall include a one-piece hinged door, a simple locking device, housing for lenses and other optical components, water-tight gaskets, terminal block and wiring. The sections shall be interchangeable and so constructed that sections can be added or removed. All exterior hardware such as hinge pins, bolts, screws, and locking devices shall be of 304 or 305 stainless steel. All interior screws and fittings shall be stainless steel or approved non-ferrous corrosion resistant material.

(a) Housing:

The housing for each signal section shall be a one-piece, corrosion resistant die cast or permanent mold cast aluminum conforming to ITE Standards.

The housing of each section shall be designed to permit access to the section for relamping without use of tools. Fittings and locking devices shall conform to the details of the Standard Drawings. The reflector, reflector ring, lamp holder, and spring wire bail shall be designed so they may be removed or replaced without the use of tools.

(b) Door:

The door shall be suitably hinged and securely held to the housing by hinge pins and locking devices.

(c) Gasketing:

Lamp holder gaskets shall be of material not affected by heat. All other gaskets, including door, lens and reflector gaskets, shall be of weather-resistant neoprene.

(d) Terminal Blocks and Wiring:

The terminal block for a standard three-section signal shall be a four-position, eight-terminal barrier-type strip mounted in the back of the middle unit. To the left of each terminal strip shall be attached the white, red, yellow, and green signal section leads and the opposite terminals shall be for field wires. The wires from the terminal block to the lamp socket shall be minimum size number 18 AWG, type TFF, 30-mil insulation thickness and rated at 105 °C.

(3) Visors:

Each signal section shall have an 11-inch to 12-inch long tunnel-type visor which shall be fabricated from number 3003 H-16 aluminum alloy. Visor shall conform to ITE Standards and details of the plans.

(4) Backplates:

Backplates shall be furnished and installed on all vehicular signal sections. Anodized aluminum sheet, 16 gage, shall be used. Dimensions shall be as shown on the plans. Backplates five inches in width shall be installed on all signal sections which are mounted on mast arms. All others shall have backplates which are eight inches in width. Louvered backplates shall be provided when shown on the plans or specified in the Special Provisions.

(5) Directional Louvers:

Where shown on the plans, directional louvers shall be furnished and installed in signal visors. Directional louvers shall be so constructed as to have a snug fit in the signal visors. The cylinder and vanes shall be fabricated from 5052-H32 aluminum alloy. Dimensions of louvers and vane configuration shall be as shown on the plans. The outer cylinder and the vanes shall be 0.032 inches minimum thickness, and the vanes shall be 0.016 inches minimum thickness.

(B) Programmed Visibility Signal Faces:

(1) General:

Each programmed visibility signal face shall conform to the provisions in Subsection 733-2.01(A), except the provisions for optical equipment shall not apply. The programmed visibility signal section shall provide a nominal 12-inch diameter circular or arrow indication.

Each section shall be provided with a sun visor and an adjustable connection that permits incremental tilting from 0 to 10 degrees above or below the horizontal axis. The visibility of each programmed visibility signal face shall be adjustable within the signal for the lanes in which traffic is to be controlled. When unprogrammed, the indication shall be visible from anywhere within 15 degrees of the optical axis.

(2) Optical Requirements:

The components of the programmed visibility signal face optical assembly shall be a circlet reflector, optical limiter-diffuser and objective lens conforming to ITE Standards. A circlet reflector with a specular inner surface shall join the lamp to the diffusion element.

The optical limiter-diffuser shall provide an image focused for objects at a distance of 900 to 1,200 feet limited by a veiling system.

The objective lens shall be a high resolution planar incremental lens, hermetically sealed with a flat laminate of weather resistant acrylic. The lens shall be symmetrical and able to be rotated to any 90-degree orientation about the optical axis.

Each signal section with a yellow indication priority programming shall provide a minimum luminous intensity of 3,000 candelas on the optical axis and a maximum intensity of 30 candelas at 15 degrees horizontally from the axis. Each section shall be capable of having visibility programmed for a minimum 3,000 candelas at two to 15 degrees horizontal from the axis. Under the same conditions, the intensities of the red indication and the green indication shall be at least 19 and 35 percent, respectively, of the yellow indication.

(3) Lamps and Dimming Devices:

The lamp for each signal section shall be a nominal 150-watt, sealed beam, 120-volt, 6,000-hour minimum rated life lamp as specified. During daylight, the signal indications shall be visible only in the lanes designated. For nighttime operation, dimming devices shall be provided to reduce the intensity by 15 percent.

(4) Terminal Blocks:

Terminal blocks shall conform to the provisions in Subsection 733-2.01(A)(2)(d).

(C) Fiber Optic Turn Arrow Signal:

(1) General:

Each fiber optic signal unit shall conform to the provisions in Subsection 733-2.01(A) except the provisions for optical equipment.

The signal unit shall display alternate legends, consisting of either a green or yellow directional arrow.

The signal unit shall be clearly legible under any lighting conditions within a 20-degree cone of vision centered about the optical axis. Visors or hoods shall have a weatherproof housing and door and shall not be required for legibility.

The signal unit shall consist of a fiber optic module with individual output lenses, color filters for specified legend colors, required light sources and transformers.

A separate lamp shall be used for each display, and lamps shall be rated between 10.5 and 10.8 volts. The rated lamp life shall not be less than 8,000 hours.

Nineteen individual lenses, 5/8 inch in diameter, shall be fitted over the end of each fiber optic bundle to form the arrow legend. The same lenses shall be used for both displays. Fiber optics shall be glass fiber bundles assembled on a flat black matrix panel. Individual fiber optic bundles shall not be jacketed or encased. The signal shall supply approximately 50 percent more light to the lenses when displaying a green arrow in order to balance the intensity between colors. No color shall appear in the lenses when not illuminated regardless of sunlight intensity.

(3) Hardware:

The complete signal unit shall be mounted in a standard aluminum 12-inch round signal case. An aluminum front panel 12 inches in diameter and lens mounts shall be colored black to minimize legibility of arrow when not illuminated.

All fiber optics, transformers, and lamps shall be mounted on the door of the unit. Lamps shall be mounted horizontally to prevent their collecting water from condensation or possible gasket leaks. No moving parts are permitted.

All screws, washers, nuts and bolts shall be corrosion resistant. All components shall be readily accessible when the door is opened. Maintenance or replacement of components shall require only simple tools.

(4) Transformers:

A separate transformer having Class A insulation rated at 48.5 volt-amps shall be used for each color display to reduce the voltage to 10.5 volts AC.

(5) Temperatures:

The fiber optic signal assembly shall be capable of continuous operation over a temperature range of -35 to +165 degrees F.

733-2.02 Pedestrian Signals:

Neon international man/hand symbol pedestrian signals shall be furnished and installed unless specified otherwise.

Pedestrian signal assemblies shall be complete and operational with the international man/hand symbol indications, and the mounting assemblies shall be furnished and installed by the contractor as shown on the plans.

(A) Neon Pedestrian Signal Indications:

(1) General Requirements:

The maximum overall dimensions of the pedestrian unit including the visor shall be 18-1/2 inches wide, 18-3/4 inches high, and nine inches deep. The man/hand symbols shall be in a single housing containing both message symbols.

The pedestrian signals shall be energy efficient, with a maximum energy usage of 20 watts, at 120 volts.

(2) Case:

The case shall be a one-piece, corrosion-resistant, aluminum alloy die casting, complete with integrally cast top, bottom, sides and back. Four integrally cast hinge lug pairs, two at the top and two at the bottom of each case, shall be provided for operation of a swing-down door.

The case shall be properly matched to other pedestrian signal components to provide a dustproof and weatherproof enclosure and shall provide easy access to replace all components.

(3) Door Frame:

The door frame shall be a one-piece, corrosion resistant, aluminum alloy die casting, complete with two hinge lugs cast at the bottom and two latch slots cast at the top of each door. The door shall be attached to the case by means of two type-304 stainless steel spring pins. Two stainless steel hinged bolts with captive stainless steel wing nuts and washers shall be attached to the case with the use of stainless steel spring pins. Latching or unlatching of the door shall not require tools.

(4) Solid State Message Module:

A molded support tray manufactured from black polycarbonate plastic shall protect the two neon tube light sources and the solid state controller.

The tube for the "Hand" symbol shall be 10 millimeters in diameter and be coated on the inside with Portland orange fluorescent material. The tubing for the "Walking Man" symbol shall be nine millimeters in diameter and be coated on the inside with lunar white fluorescent material. Both shall be formed and positioned for maximum intensity.

The message lens shall consist of a 1/8-inch minimum thickness clear U.V.-stabilized, refractor-type polycarbonate plastic with outer prisms and shall be heat, craze, and water resistant.

The two neon compartments shall be sealed into an integral assembly with a one-piece sponge gasket fitted around the perimeter to protect the enclosed neon tubing from handling and weather.

Solid State circuitry shall be assembled on circuit boards as necessary to energize to high voltage flyback transformers and the neon tubes.

Each controller circuit shall be sealed into an integral assembly with a one-piece sponge fitted around the perimeter to protect the enclosed neon tubing from handling and weather.

The entire unit including neon tubing and solid state controller shall have a factory warranty of five years against defects in workmanship or materials.

Each controller circuit shall be powered from 120-volt AC, 60-hertz and shall have a power factor of 90 percent minimum.

(5) Messages:

Messages shall be the Portland orange "Hand" and the white "Walking Man" illuminated by multiple configuration neon tubes encased in the plastic solid state message module. The symbols shall be a minimum of 12 inches in height and seven inches in width and shall be configured as shown in the MUTCD.

The inside face of the message lens shall be painted in all areas except where the desired symbols are formed. The first coating of paint shall be black to form a contrasting background. The second coating shall be white to reflect internal light in between symbols.

(6) Visors:

The visor shall be the crate type to eliminate sun phantom and shall be 1-1/2 inches deep.

The crate assembly shall contain a minimum of 21 zigzag-pattern horizontal louvers and 20 straight horizontal louvers. Every other formal louver shall be reversed to form one-inch diamond shaped cells. The material used for the visor shall be 0.030 inches thick and shall be 100 percent impregnated black polycarbonate plastic with a flat finish.

(B) Incandescent Pedestrian Signal Indications:

(1) General Requirements:

Each incandescent pedestrian signal shall consist of a housing, two-color message plate, a reflector assembly, two incandescent lamps and a front screen.

The pedestrian signal shall be furnished complete with incandescent lamps as described herein.

The overall maximum dimensions of each housing, including the front screen, shall be 18-1/2 inches wide, 18-3/4 inches high, and 11-1/2 inches deep.

(2) Case and Door Frame:

The case and door frame for the incandescent pedestrian signals shall conform to the requirements of Subsection 733-2.02(A).

(3) Message Lenses:

Each message lens shall be one-piece and shall be made of 1/8-inch minimum thickness, ultraviolet-stabilized polycarbonate or 3/16-inch thick tempered glass. Either lens shall have a textured outside surface to eliminate message "hot spots".

(4) Reflector:

Each reflector shall be a single-piece double-parabolic reflector constructed from textured plastic or aluminum. All reflectors shall conform to the requirements of ITE Standards. Plastic reflectors shall consist of vacuum-formed polycarbonate with a vacuum-deposited aluminum reflector surface and shall not distort when used with a lamp of specified wattage normally used in the signal.

(5) Lamp Holder:

Each lamp holder shall be positioned so as to be centered and pre-focused in its respective position when an A21 bulb with medium base is used. The lamp holder shall be made of molded phenolic and shall have a brass screw shell with lamp grip.

(6) Visor:

Each incandescent pedestrian signal shall be provided with an egg-crate type visor designed to eliminate sun phantom.

The crate assembly shall consist of 15 vertical members and 26 horizontal members plus two integral locking strips to prevent vandalism. The vertical spacing of the horizontal member shall be 1/2 inch. The completed egg-crate portion shall be 1-1/2 inches deep.

The material for the crate visor shall be as specified in Subsection 733-2.02(A)(6).

(7) Wiring and Terminal Blocks:

Each lamp socket for incandescent pedestrian signals shall be provided with one red lead for "Hand" symbol and one green lead for "Walking Man" and one white lead from the shell. Leads shall be number 18 AWG and shall be wired to respective terminals of a three-terminal block. The two white wires shall be connected to a common terminal.

733-2.03 Flashing Beacons:

Flashing beacons shall consist of one or two signal sections as designated on the project plans, conforming to the provisions in Subsection 733-2.01(A). A yellow or red lens shall be used as specified on the project plans.

(A) Overhead Flashers:

The overhead flashing beacon shall consist of two signal sections mounted on a cantilever arm assembly. Each overhead assembly shall incorporate 12-inch signal sections with

yellow lenses unless otherwise specified. The "Signal Ahead" sign to be mounted on the mast arm will be furnished by the Department unless otherwise specified.

(B) Pole Flashers:

Each pole flasher shall consist of two signal sections. Each pole flasher assembly shall contain eight-inch signal sections with yellow lenses.

(C) Control Equipment Housing:

The control equipment housing shall be a Type I load center cabinet as shown in the plans unless otherwise specified.

733-2.04 Mounting Assemblies:

Mounting Assemblies shall consist of terminal compartments and assemblies of 1-1/2 inch nominal standard pipe and fittings. All members shall be so fabricated that they shall provide plumb, symmetrically arranged, and securely fabricated assemblies.

Terminal Compartments: A terminal compartment shall be assembled in the mounting brackets as shown in the Standard Drawings. The terminal compartment shall be manufactured of bronze, Type 356-T6 aluminum, or ductile iron.

Each terminal compartment shall be fitted with a 12-position, 24-terminal block. Each type of mounting assembly shall be supplied with wiring from the terminal block through the support arm which holds the signal. This wiring shall be in the form of color-coded wire leads with spade terminals for connecting to signal head, and soldered ends for connecting to terminal strips in the terminal compartment. The wiring shall be colored-coded as follows:

White	Common to all heads
Red	Red lens head
Yellow	Yellow lens head
Green	Green lens head

The leads shall be minimum number 16 stranded AWG Type-THW with 30-mil thermoplastic insulation. Leads shall be of sufficient length to extend from the center section of the signal head to the top of the terminal compartment. Terminal compartment wire hookup shall be as follows:

Top terminal	Phase A Red
Next terminal	Phase A Yellow
Next terminal	Phase A Green
Next three terminals	Phase B R-Y-G
Bottom terminal	Common - White

A rainproof cover shall be provided for all terminal compartments which will provide ready access to the internal terminal block wiring.

The types of frameworks used and the methods of mounting them shall be as shown on the plans or specified in the Special Provisions.

733-3 Construction Requirements:

Construction shall be such that all conductors are concealed within assemblies. Cable guides shall be used to support and protect conductors entering through poles. All threads shall be coated with rust-preventive paint during assembly.

Each vehicle, pedestrian signal, or flasher assembly shall be mounted at the location and in the manner shown on the project plans.

When signal faces are mounted on a mast arm, the plumbizer when specified shall be placed on the mast arm, and a 3/8-inch by four-inch bolt shall be used to fasten both together.

Materials removed and not designated to be salvaged or incorporated into the work shall become the property of the contractor.

All traffic signal heads not in use shall be covered with burlap and shall be unmistakably out of service when observed by an approaching driver. Plastic coverings shall not be allowed.

733-4 Method of Measurement:

Traffic signal faces, pedestrian signal faces, traffic signal mounting assemblies and flashing beacons will be measured as a unit for each type of signal face, mounting assembly or flashing beacon furnished and installed or modified.

733-5 Basis of Payment:

The accepted quantities of traffic signal faces, pedestrian signal faces, traffic signal mounting assemblies and flashing beacons, measured as provided above, will be paid for at the contract unit price each, for the type signal face, mounting assembly or flashing beacon designated in the bidding schedule, complete in place, which price shall be full compensation for the work described and specified herein and on the plans, including visors, backplates, lamps and all hardware necessary to provide a complete, functional, traffic signal installation.

No direct payment will be made for assembly of Department-furnished items, the cost being considered as included in the contract price bid for the item in place.

SECTION 734 TRAFFIC CONTROLLER ASSEMBLY:

734-1 Description:

The work under this section shall consist of furnishing and installing traffic controller assemblies at the locations shown on the project plans and in accordance with the details shown on the plans and the requirements of these specifications.

A traffic controller assembly shall consist of a complete assemblage of electrical equipment and components for controlling the operation and timing of traffic control signals.

734-2 Materials:

The controller assembly shall include the controller unit, all necessary auxiliary equipment, the controller cabinet, concrete foundation, conduit, elbows, anchor bolts and clearance pad.

The auxiliary equipment shall include all appurtenances such as flasher controls, loop detector amplifiers, power assemblies, signal load switches, conflict monitors, pre-emptors, controllers, coordinators, time switches, external logic, lighting controls, cabinet wiring and accessories as indicated on the plans or in the Special Provisions.

The entire surface area of each circuit board shall be sealed to protect against moisture.

The following auxiliary equipment shall be furnished with all wired traffic controller assemblies when required:

- Controller
- Power Panel
- Signal Load Switches
- Signal Conflict Monitor
- Detectors
- Controller Flasher Assembly
- Flash Switches
- Surge Protector
- Radio Interference Suppressor
- Cabinet Ventilation Fan
- Terminal Tie Points
- Field Terminals

734-2.01 General Requirements:

The traffic controller assembly equipment shall conform to the requirements of the current edition of NEMA Publication TS-1.

(A) Documentation:

The contractor's material proposal shall include complete technical information, shop drawings, photographs, graphs, circuit diagrams, instruction manuals, and any other necessary documents to fully describe the proposed traffic controller assembly items.

At the time of delivery, the contractor shall furnish three sets of instruction books and an itemized price list for each type of equipment, their sub-assemblies, and their replacement parts.

The instruction books shall include the following information:

- Table of Contents;
- Operating Procedure;
- Theory of Operation;
- Step by step maintenance and trouble-shooting information for the entire assembly and for all components capable of being adjusted;
- Circuit Wiring Diagrams;
- Pictorial Diagrams of Parts Locations; and
- Parts Numbers.

The instruction manuals shall include itemized parts lists. The itemized parts list shall include the manufacturer's name and part number for all components (such as transistors, integrated circuits, diodes, switches, resistors, capacitors, relays, etc.) used in each circuit module. The list shall also include cross-references to parts numbers of other manufacturers who make the same replacement part.

(B) Warranties:

Each controller unit and all of its auxiliary equipment shall be warranted by the supplier against all defects in materials and workmanship in accordance with Subsection 106.13 with the additional requirements as specified hereinafter.

The warranty for the controller unit and its auxiliary equipment shall provide that in the event of malfunction during the warranty period, a like controller unit, module, or auxiliary equipment shall be furnished, within three working days, for use while the warranted unit is being repaired. The isolation of any malfunction and the repair and/or replacement of any device within the warranty period shall be the responsibility of the supplier.

The Department reserves the right to reject equipment of a specific model type in which the Department has determined that its past field performance has been unsatisfactory. The Department's rejection of an item shall be final.

(C) Certificate of Compliance:

A Certificate of Compliance conforming to the requirements of Subsection 106.05 shall be submitted for each traffic controller assembly. The Department reserves the right to require Certificates of Compliance for each controller assembly component.

The Department reserves the right to perform tests on any equipment supplied by the contractor in the Department's testing facilities.

(D) Pre-Approval of Controller Equipment:

The Department will only accept equipment furnished by manufacturers or vendors with proof of liability insurance for controller units, conflict monitors, load switches, flashers, and flash relays, and which have been pre-approved by the Department.

All traffic signal controller units shall be tested by the Department's testing procedures and be pre-approved by the Department. Pre-approved traffic signal controller units will be listed in the Special Provisions. Any controller unit and specified component not listed in the Special Provisions will not be accepted.

The Department reserves the right to re-test any pre-approved equipment supplied by the contractor in the Department's testing facilities.

(E) Department Testing of Control Equipment:

A completely wired controller assembly with wiring diagrams and instruction books shall be delivered for inspection and testing unless otherwise specified. The equipment shall be delivered to:

Arizona Department of Transportation
Traffic Operations Services
Traffic Signal Shop
2104 South 22nd Avenue
Phoenix, Arizona 85009

It shall be the responsibility of the contractor to correct or replace any equipment that fails Department testing. Such corrections or replacements shall be as directed by the Engineer.

(F) Department Testing Procedures of Bid Items:

The traffic controller assembly shop test procedure shall be as follows:

- (1) The contractor shall deliver the equipment to the Traffic Signal Shop.
- (2) The Department will take inventory of the delivered equipment.
- (3) The Department will conduct a load test for a minimum of 72 hours under on-line conditions.
- (4) Environmental or other tests will be performed by the Department at the discretion of the Engineer.
- (5) After any test failures, the contractor shall have three working days to correct the failure. Procedures (3) and (4) above shall then be repeated until the equipment passes the tests. The Engineer may require the replacement of any component after that component's second failure under test.

- (6) After the controller operation tests are approved, the contractor shall pick up the control cabinet and equipment, haul them to the job site, and install them as specified. After the contractor has mounted the control cabinet on the cabinet foundation, Department personnel will connect all the field wiring inside the control cabinet and test the signal circuits.
- (7) Scheduling the activation of traffic signals shall require a minimum of 10 working days notice to the Department's Electrical Inspection Unit at 2104 South 22nd Avenue, Phoenix, Arizona 85009, (602) 712-7312. No activations outside the Phoenix metropolitan area shall be scheduled either on Monday or Friday. The Contractor shall be responsible to ensure that all the required work has been completed and that the traffic signals are ready to be activated on the pre-arranged date. If the Department determines that the traffic signal work is not complete and cannot be activated, then the contractor shall be responsible for costs incurred by the Department (personnel, equipment, lodging, per diem, salary etc.).

734-2.02 Traffic Signal Controllers:

A traffic signal controller shall consist of an electronic device dedicated to the selection and timing of traffic movements. Each controller shall provide all the features, functions and phasing operations as indicated on the plans and the Special Provisions.

(A) Solid State Digital Controllers:

The solid state digital controllers shall utilize modular construction, solid state circuitry, and digital timing techniques. Integrated or discrete semiconductor devices shall be used exclusively.

Controller logic shall have high noise immunity.

Solid state components shall be standard production types and shall be readily available.

Components shall be properly rated with respect to heat dissipating capacity and rated voltage.

The minimum rated life of all components shall be 10 years under 24-hour-a-day operation.

Components shall be clearly identifiable by markings on circuit boards or parts numbers on pictorial diagrams.

The digital timing techniques and repeatability shall be accordance with:

(1) Module Circuit Boards:

The controller shall contain plug-connected module boards. The solid state components shall be mounted on printed circuit module boards.

The module boards from the controller shall be easily removed without the use of special tools and shall be designed to permit replacement of all components without damage to the board or its circuits. Each individual printed circuit board shall be identified by a serial number or parts number clearly stamped or etched on the board.

The module circuit boards shall be arranged by functional groupings.

Each module board by functional design shall be electrically and mechanically interchangeable with other controllers of the same model, controller series, or frame type.

The module boards shall be fabricated from epoxy glass laminate NEMA grade G-10 or G-11, with a minimum weight of two ounces of copper per square foot. The copper track shall have adequate cross-section to carry the designed current capacity. All contact surfaces shall be non-corrosive construction. The entire surface area of each circuit board shall be sealed to protect against moisture.

Phase timing modules which time more than one phase shall be programmable to permit the selective disabling of unused phases.

Modules that have a 120-volt AC input shall be properly fused within the controller.

The interfaces and the power supply for the controller shall be designed to accommodate the maximum module configuration possible for the controller such that no additional future modifications are required.

Interchangeable connectors (except data buss type) shall be keyed to prevent their insertion into the wrong receptacle of the controller.

The controller's housing shall be an integral frame assembly constructed of non-ferrous metals. The housing shall conform to all NEMA requirements.

(2) Volatile Memory:

All volatile memory in controllers, time switches, and time base coordinators shall utilize a battery back-up supply to maintain memory as follows:

- (a) Complete memory retention for 30 days if RAM board is removed from controller.
- (b) Non-rechargeable Battery: The non-rechargeable battery shall be rated to maintain memory for not less than five years in continuous use and include a battery condition indicator.
- (c) Rechargeable Battery: The rechargeable batteries shall be the type that can be operated, stored, or charged in any position and be capable of being recharged not less than 1,000 times. The rechargeable batteries shall have an automatic battery charger with a battery discharge indicator and shall operate within the NEMA environment standards.

(3) Indicators:

Indicators shall be the sub-miniature type and may be either incandescent lamps or solid state. Incandescent lamps shall be replaceable from the front of the panel.

All programming pins shall be the printed circuit receptacle, non-corrosive, turning fork type. The pin contactor shall fit any standard 0.055-inch to 0.73-inch board. The pin shall be rated for 600 volts and five amperes.

(B) Digital Pre-Timed Solid State Controllers:

The DPT controller shall designate a digital pre-timed controller compatible with NEMA standards, these specifications, the Special Provisions, and the plans.

The Type DPT controller shall be designated with six-position alphanumeric code. The two numbers in the code shall have the following meanings:

DPT18_ - Capacity of up to 18 signal load circuits

DPT40_ - Capacity of up to 40 signal load circuits

The letters in the last position shall have the following meanings:

DPT__S - Computer Supervised Unit

DPT__P - Programmed for Pre-emption

DPT__T - Programmed for Time Base Coordination

DPT__H - Hard Wire Intertie

When the last position has more than one letter, the controller shall have all the functional features defined by each letter.

All the DPT controller units supplied shall be readily programmable for pre-emption and shall include the time base coordination module and programming.

(1) The DPT18 Pre-Timed Controller:

The DPT18 shall meet the following specifications and shall be designed for non-actuated operation of traffic signals having pre-determined cycle lengths, cycle lengths, interval durations, and interval sequences.

The controller shall have three independent cycles with three offsets and two splits per cycle. Cycle lengths shall be front panel adjustable with a front panel cycle-in-effect indicator. The cycle display shall show the local elapsed time, inputs, outputs, and timing values.

The controller shall have 10 signal intervals and 18 independently controlled on/off signal circuit outputs which may be independently programmed for flashing the signal output in a designated interval.

The controller unit for replacement for a type-F electromechanical controller shall be a retrofit back panel 22.5 inches high, 13.0625 inches wide, and 10.3125 deep. The back panel shall house NEMA-type flasher, load switches, and two-channel card rack amplifier. The flasher transfer relays shall be interfaced with a Cinch-Jones type eight-pin socket. The signal load shall be controlled by a 60-ampere tungsten mercury contactor.

(a) Indicators:

Indicators shall include digital read-outs to display all inputs, countdown timing intervals, cycle, split, local master and pre-emption.

(b) Controller Programming:

Program entries shall be front panel programmable without the use of tools or software.

(c) Pre-emption:

Pre-emption functions shall be programmable assignments to include entrance times, track clearance (passage and clearance times), minimum duration protection time, and exit. The programming shall also include detection mode, pedestrian indications operation, delay time, and flash operation.

(d) Vehicle Detection:

The back panel shall include card-rack mounted NEMA-type vehicle detector for two detector channels. Each channel shall input each actuated vehicle signal phase group.

(e) Pedestrian Detection:

The actuated signal phase groups shall have pedestrian actuated movements.

(f) Start-Up and Flash:

The start-up operation and flash operation intervals and timing shall be programmable in the unit.

(g) Control Cabinet for DPT18 T/H:

The control cabinet shall be the type specified on the plans and in the Special Provisions.

The control cabinet shall include the following items: cabinet fan, light, convenience outlet, and police panel.

The following switches shall be included: main-on/off, controller auto on/controller on-flash/controller off-flash, signal lights on/off, and auto/manual.

The following switches shall be mounted inside the police panel: main switch, auto/flash switch, and auto/manual switch, and manual control cord.

(h) Conflict Monitor:

The conflict monitor shall be a cable-connected unit, external, shelf mounted, six channel, NEMA-wired to monitor all functions. All the equipment housed in the control cabinet shall be installed and removed from the front with ease.

(2) The DPT40 Pre-Timed Controller:

The DPT40 shall be designed for non-actuated operation of traffic signals with pre-determined cycle lengths, interval durations, and interval sequences. The controller unit shall have a minimum of three independent cycles. Each cycle shall have a minimum timing range of 0-255 seconds and interval timing of 0-25.5 seconds, in one-second and one-tenth-second increments. Each cycle length shall be front panel adjustable with a front panel cycle-in-effect indicator. A cycle read-out shall show the time of the local cycle that has elapsed.

Each cycle shall have three offsets and four splits. The four splits (signal interval plans) shall be selected by either a remote interconnect, time switch, or a local detector actuation. The controller unit shall have 31 signal intervals and 40 independently controlled on/off signal circuit outputs which may be independently programmed for flashing the signal output in a designated interval.

(a) Synchronization:

The pre-timed controller unit shall have a manual switch to synchronize itself with an intertie system input, or the controller unit shall be capable of providing a sync-pulse to an intertie system when programmed to be a master controller unit.

(b) Interconnected System:

The controller unit shall be capable of operating with an existing master controller unit with six of 10 functions. The controller unit inputs from a standard-type pre-timed interconnect shall be as follows:

Dial	2	One Input
	3	
Offset	1	
	2	
	3	
Split	1 *	
	2 *	

	3 *	
	4 *	
Flash		
Common		AC neutral
*Note: Splits 1, 2, 3, and 4 shall be used with a 10-function intertie system only.		

Dial 1 shall be in effect when neither the Dial 2 nor the Dial 3 lines are energized.

A master controller unit with direct control by a computer system shall have NEMA-logic level inputs.

(c) Conflict Monitor:

The conflict monitor shall be an external shelf-mounted, 12-channel or larger NEMA cable-connect unit wired to monitor all functions.

(d) Manual Control:

An auto-manual control switch and wiring terminals shall be furnished in the controller cabinet assembly for a momentary contact hand held switch. The auto-manual control switch shall be accessible with a standard police type key. The hand-held manual switch shall be weather-proof on a retractable cable.

Manual operation of the controller shall provide the same color sequence as was programmed for the automatic operation. The duration of all intervals, except the yellow vehicle interval and the red vehicle clearance interval, shall be controlled by operation of the manual switch. Duration of the yellow interval and red clearance interval shall be the minimum time specified to be programmed in the controller unit.

(e) Minimum Timing:

A guaranteed minimum back-up time for each interval, programmed in accordance with the signal plan non-volatile programmable read-only memory, shall be provided as specified on the plans or in the Special Provisions.

(f) Manufacturer Programmed Functions:

The following functions shall be programmed by the manufacturer into the programmable read only memory in accordance with the signal plan specified on the project plans:

- 1) **Start-up programs:**
- 2) **Each signal plan and sequence programs:**
- 3) **Back-up times:**
- 4) **Remote flash operation programs:**

- 5) **Cycle back-up times:**
- 6) **Offset back-up times:**
- 7) **Pre-emption plan and sequence programs:**
- 8) **Field programmable functions:**

The following functions shall be programmable from the front panel by the operator in the field:

Timing Entry;
 Cycle Lengths;
 Offsets;
 Interval Time;
 Read-out of cycle, split, and interval;
 Read-out of Timing in the PROM; and
 Pre-Emption Interval Timing.

9) Function Switches:

The following function switches shall be provided:

Lock/Non-Lock - Recall for each detector
 Local/Remote selection of cycle, offset, split and plan
 Sync/Hold for non-interconnected operation

The programming of the timing entry, cycle, offsets, selectable functions, and phase timing intervals shall be set by entry switches, programming pins or by keyboard entry. Programming shall include digital solid state read-outs of keyboard programmed functions.

10) Input-Output Connectors:

The signal output connectors shall be compatible with the NEMA four-phase controllers. The controller unit shall use the standard NEMA connectors A and B per NEMA table 13-3, four-phase terminations, and the following tables:

CONNECTOR A			
Pin No.	Function	Pin No.	Function
A	Reserved	<u>f</u>	Det. 1
B	24-Volt DC	<u>g</u>	Det. 5
C	Voltage Monitor	<u>h</u>	Det. 9
D	Sig. Ckt. # 3	<u>i</u>	-
E	Sig. Ckt. # 6	<u>j</u>	Remote Flash
F	Sig. Ckt. # 10	<u>k</u>	Guar. Interval
G	Sig. Ckt. # 13	<u>m</u>	-
H	Sig. Ckt. # 12	<u>n</u>	Signal Plan 2 (Preempt 1)

CONNECTOR A			
Pin No.	Function	Pin No.	Function
J	Sig. Ckt. # 11	<u>p</u>	AC +
K	Det. 2	<u>q</u>	Master Sync (Out)
L	Det. 6	<u>r</u>	Spare
M	Det. 10	<u>s</u>	Sig. Ckt. # 1
N	Stop Time	<u>t</u>	Sig. Ckt. # 4
P	Coord. Sync (IN)	<u>u</u>	-
R	External Start	<u>v</u>	-
S	Manual (Interval Advance)	<u>w</u>	Overlap Advance
T	Indicator Lamp Control	<u>x</u>	Free
U	AC -	<u>y</u>	Cycle 2
V	Chassis Gnd	<u>z</u>	Split 4
W	Logic Gnd	AA	Signal Plan 3 (Preempt 2)
X	Flash Logic (1PPS)	BB	O'L Mode
Y	Spare	CC	Spare
Z	Sig. Ckt. # 2	DD	Sig. Ckt. # 7
<u>a</u>	Sig. Ckt. # 5	EE	-
<u>b</u>	Sig. Ckt. # 9	FF	Signal Plan
<u>c</u>	Sig. Ckt. # 8	GG	Split 2
<u>d</u>	-	HH	Cycle 3
<u>e</u>	Sig. Ckt. # 14		

CONNECTOR B			
Pin No.	Function	Pin No.	Function
A	Free Output	<u>f</u>	Spare
B	Flash Cont.	<u>g</u>	Spare
C	Spare	<u>h</u>	Det. 12
D	Sig. Ckt. # 15	<u>i</u>	Det. 11
E	Sig. Ckt. # 16	<u>j</u>	Cycle 4 (Optional Function)
F	Sig. Ckt. # 17	<u>k</u>	-
G	Sig. Ckt. # 24	<u>m</u>	-
H	Sig. Ckt. # 26	<u>n</u>	-
J	Sig. Ckt. # 27	<u>p</u>	Sig. Ckt. # 30
K	-	<u>q</u>	Sig. Ckt. # 31
L	Det. 4	<u>r</u>	-
M	Det. 8	<u>s</u>	Sig. Ckt. # 21
N	Det. 3	<u>t</u>	Spare
P	Det. 7	<u>u</u>	Sig. Ckt. # 40
R	Offset 3	<u>v</u>	-
S	Offset 2	<u>w</u>	Sig. Ckt. # 38
T	-	<u>x</u>	-
U	Offset 1	<u>y</u>	-
V	CMU Stop Time	<u>z</u>	-
W	Split 3	AA	Sig. Ckt. # 29
X	-	BB	Sig. Ckt. # 36

CONNECTOR B			
Pin No.	Function	Pin No.	Function
Y	Sig. Ckt. # 18	CC	Sig. Ckt. # 37
Z	Sig. Ckt. # 19	DD	Sig. Ckt. # 34
<u>a</u>	Sig. Ckt. # 20	EE	Sig. Ckt. # 39
<u>b</u>	Sig. Ckt. # 22	FF	Sig. Ckt. # 32
<u>c</u>	Sig. Ckt. # 23	GG	Sig. Ckt. # 35
<u>d</u>	Sig. Ckt. # 25	HH	Sig. Ckt. # 33
<u>e</u>	Sig. Ckt. # 28		

The following inputs shall be in accordance with NEMA:

Stop Timing	shall have the effect of halting the local percent counter.
Manual Enable	guaranteed interval inhibit.
Interval Advance (Manual)	shall step controller through each programmed interval sequentially. Shall operate on trailing edge of pulse. When asserted with stop timing shall provide manual control of all intervals.
Indicator Lamp Control	shall extinguish all front panel indicators.
External Start	shall force the controller to the specified starting interval. The normal cycle shall resume immediately upon release of this input.
Detectors, Chassis Ground, and Pre-Emption.	

The following outputs shall be in accordance with NEMA:

Signal Output Circuits:	
Interval 1 On	shall be active for the duration of interval 1.
Voltage Monitor	shall be active as long as the controller is providing proper operation.
+ 24 volts DC	
Logic Common	
Master Sync	shall be active at all times except during the master sync period.
Flash Logic	shall alternate between true-false logic levels at a one pulse per second repetition rate.

11) Pre-Emption:

When specified, a pre-emption program shall be provided in the controller software. The pre-emption program shall be initiated by a non-locking pre-emption call. The pre-emption mode shall have its own timing, including minimum timing and signal plan.

12) Electrical Characteristics:

The controller programs provided by the manufacturer shall be permanently stored in a non-volatile memory such that batteries shall not be required to maintain the minimum interval timing, interval sequences, start-on, offsets, cycle and splits, flash on/off, detectors, signal circuits flash, and pre-emption.

(C) Actuated Solid State Digital Controllers:

(1) General:

The actuated solid state digital controller shall be designed for the operation of traffic signals with fully actuated or semi-actuated timing of the traffic signals including operation with auxiliary equipment.

Each actuated controller shall be furnished with the required number of phases, phase sequence, phase timing features, and all other control functions that are specified herein, on the plans, or in the Special Provisions.

(2) DAN-Actuated Controller and Features:

Actuated controllers shall be designated on the plans or Special Provisions with the following designations:

The DAN controller shall designate a digital actuated controller conforming to NEMA Standards, these specifications, the Special Provisions, and the plans.

The number in the alphanumeric code type shall mean the following:

DAN-2 Two-phase controller

DAN-4 The controller shall be capable of operating four phases.

DAN-8 The controller shall be capable of operating eight phases.

(a) Phase Timing:

Each DAN controller unit phase timing or phase module shall include timing periods for each vehicle and pedestrian phase actuated with volume density timing, or non-actuated timing for semi-actuated phase operation. Each phase timing period shall be not less than the minimum required by NEMA.

(b) Controller Pre-Approval:

The DAN controller pre-approval shall be in accordance with current NEMA specifications and these specifications. No additional functions shall be in the DAN controller. Pre-approval tests and evaluations shall be performed by the Department and approved by the Engineer.

(c) Overlap Phases:

Controllers with more than two phases shall be furnished with a NEMA 14-9 overlap program board and driver outputs. The NEMA-type overlaps shall be programmed by the NEMA program board assembly with hard wire jumpers easily accessible inside the controller, or programmed in the controller without the use of tools.

(d) Frame Sizes:

The controller unit frames shall be two-, four-, and eight-phase, not exceeding the NEMA-specified dimensions, except height which shall be 17 inches maximum. Equipment shall be interchangeable in the controller cabinet.

(e) Phase Sequence Operation:

Each phase and associated overlap phases of a single-ring controller shall be sequentially timed as indicated on the plans.

Dual-ring controllers shall be sequentially timed per ring and concurrently timed per non-conflicting phase. Dual-ring controllers shall be programmed for the dual entry mode of operation.

Dual-ring traffic signal controllers that are PROM programmable shall include three PROMS, one installed PROM, and include two spare phase sequence PROMS as follows:

PROM A - Eight-phase, quad left turn operation.

PROM B - Eight-phase, dual left turn ring one operation, sequential ring two operation.

PROM C - Eight-phase sequential operation.

The two spare PROMS shall be identified and packaged for future use.

(f) Controller Input-Output Functions and Connectors:

The controller shall provide all the NEMA input/output functions. The A, B, and C Connectors and their pin assignments shall be the same as shown in Table 13-3 of 1983 NEMA for two-, four-, and eight-phase controller units and their cables.

All A and B connectors and cables shall include specified four- and eight-phase functions, for future use.

Auxiliary connectors shall not be permitted on Type DAN controllers.

(g) Standard Functions:

Standard controller functions specified by NEMA, and as specified in these specifications shall be furnished.

The controller unit functions shall include NEMA TS-1, Sections 13 and 14.

The standard functions shall be the NEMA-specified features on a per phase, per ring, and per unit basis.

(h) Pre-Programmable Guaranteed Minimum Clearance Timing:

All controllers shall have a guaranteed minimum clearance timing program and shall be programmed as follows:

- (1) Guaranteed yellow change interval: three seconds
- (2) Guaranteed pedestrian clearance interval: five seconds
The controller shall have the capability to permit exclusive pedestrian phase when required.

(i) Pre-Programmable Backup Timing:

All controllers with a backup timing PROM capability shall be programmed for the type of phase movement for the minimum times as follows:

Any Vehicle and Pedestrian Phase Movement (Non-Actuated)	
Interval	Time in Seconds
Minimum Green	25
Walk (Solid)	7
Ped Clearance (Flashing)	10
Yellow Change	4
Red Clearance	2

Any Vehicle and Pedestrian Phase Movement (Actuated)	
Interval	Time in Seconds
Initial Green	10
Vehicle Extension (Passage)	3
MAX I	25
MAX II	30
Walk (Solid)	7
Red Clearance (Flashing)	10
Detector Memory	ON
Recall Mode	PED.

Any Vehicle Exclusive Turning Phase Movement	
Interval	Time in Seconds
Initial Green	8
Vehicle Extension (Passage)	2

Any Vehicle Exclusive Turning Phase Movement	
Interval	Time in Seconds
MAX I	20
MAX II	25
Yellow Change	4
Red Clearance	2
Detector Memory	ON
Recall Mode	Vehicle

Any required change or additions by the manufacturer to these time values shall be cleared through the Engineer before delivery of the controller assembly.

(3) The MPS Controller & Features:

The MPS controller shall designate a digital microprocessor controller that conforms to all the DAN controller specifications, and shall include special programmable applications as specified in these specifications, and the plans.

(a) MPS Controller Minimum Phase Requirements:

The MPS Controller shall be a four-phase or eight-phase dual ring operation or twelve-phase dual or three ring operation as required in the plans.

The type of MPS controller shall be designated by the special program applications required.

The last letters shall designate the following:

MPS-SI	Computer Supervised Unit - Interconnected
MPS-SD	Computer Supervised Unit - Dial Up
MPS-P	Programmed for Pre-Emption
MPS-T	Programmed for Time Base Coordination
MPS-C	Programmed for TM Coordination - Traffic Actuated Coordination
MPS-M	Arterial Master Controller - Interconnected
MPS-SF	Programmed for any additional Special Functions per Special Provisions.

The MPS controller shall include the following features:

- (1) Each MPS controller shall include the programming and module for Time Base Coordination with a front panel "D" connector, or auxiliary connector for all non-NEMA functions.

- (2) All non-NEMA input/output functions shall be contained in a system or "D" connector only.
- (3) Each MPS controller shall include the printer interface and port. The printer interface shall permit printout of all controller, coordinator, and pre-emptor operator entered data.
- (4) The "D" Connector shall be located on the front panel.
- (5) The MPS controller main frame shall be readily compatible for MPS-P pre-emptor programming.

(b) MPS Controller Pre-Approval:

In addition to meeting the DAN controller pre-approval requirements, the Department will require each MPS controller model and special program type to be tested and evaluated on a program-by-program basis before approval by the Engineer. Each approval will be limited to each type of program required by the Department, not by manufacturer or model. The number of manufacturers pre-approved by the Department may be limited for each type of program the Department requires.

Existing Department approved controller programs shall be limited to the manufacturer's program version and model currently in operation for a specified geographic area as required by the Engineer.

Approval of a MPS arterial or interconnected supervised controller unit shall be limited to the Department's operating computer management software and hardware.

(c) MPS Twelve-Phase Controller:

The twelve-phase controller shall meet all DAN controller specifications plus the following functions:

- (1) All non-NEMA functions and phases shall be contained in a "D" connector or auxiliary connector on the front panel.
- (2) The controller shall include twelve phases with both vehicle and pedestrian timing.
- (3) The controller shall have allocation of phases to be operated in a special programmable concurrent phase or co-phase mode. Up to six phases may be used as co-phases. The co-phases shall be capable of being implemented to create additional rings. The co-phase timing parameters shall be entered from the front panel.
- (4) The controller shall contain two additional overlaps to the four NEMA overlaps.

- (5) The controller shall include Time Base Coordination and three pre-emption programs.
- (6) The controller shall accept up to sixteen detector inputs.

(d) MPS - Coordination Programming Pre-Approval:

The MPS-S computer supervised controller and the MPS-M arterial master controller for systems shall be pre-approved by the Engineer per the Department's computer hardware and software requirements.

The MPS-C TM coordination and MPS-T time base coordination shall be pre-approved by the Engineer per the Department's system requirements. Each manufacturer's unit shall be readily interchangeable within the same model line.

(e) MPS-T Time Base Coordination Program:

- (1) The MPS-T program for time base coordination shall be included in each MPS controller unit.

The MPS-T program shall consist of the hardware, software, and cabinet wiring to provide coordinated traffic flow without the use of interconnect cables between controller units in a dedicated geographic area. The MPS-T program shall be supervised by its own clock, which will monitor the program's memory so as to implement routine time of day, day of week, and week of year programs; as well as automatic daylight savings selection.

- (2) The MPS-T controller program shall include the following functions:

- (a) Shall be capable of being system interfaced (intertie or dial-up) for a program monitoring and data down-loading and system data up-loading. The data down-loading and clock updating shall also be accomplished by a hand-held device.

- (b) The coordination programming shall include the following phase timing options: The MPS-T Controller shall have a coordination system "D" connector. The system connector shall function as input/output port and auxiliary output connector. All outputs shall be NEMA compatible.

- (c) The MPS-T Controller shall provide for all time base coordination, user program data input, and the status read-outs, including cycle countdown and program data display, on the front panel.

(f) MPS-T Controller Cabinet Wiring:

The following cabinet wiring functions shall be included with the MPS-T controller cabinet assembly:

- (1) The cabinet shall be wired for call to non-actuated mode I for the highway and mode II for cross street, unless otherwise specified.
- (2) The inside cabinet switch panel shall include a switch for coordination, and free run modes of the coordinator program. The remote free input shall be wired to a cabinet terminal tie point.
- (3) Two auxiliary time of day (24 hour) outputs shall be wired in the cabinet to program special functions via the coordination system "D" connector.

(g) MPS- Pre-Emption Programming:

The MPS Controller shall include all the required hardware and CPU software so as to readily accept the addition of a MPS-P program.

The MPS-P pre-emptor programmed controller unit shall be pre-approved by the Engineer as per the Department's requirements for any geographic area or system. Each manufacturer's unit shall be readily interchangeable within the same model line.

The MPS-P pre-emptor program shall include all required hardware and programming with an input/output connector cable interface. The removal of the pre-emption module shall not interfere with the normal operation of the controller unit.

The MPS-P controller shall have the pre-emption user program data inputs and status read-outs, including pre-emption intervals and program data, displayed on the front panel.

The following is an outline for a MPS-P program scheme. Each MPS-P program shall be evaluated by this scheme.

1) Pre-emptor Intervals:

The pre-emptor shall control intervals by ring. Before the initiation of pre-emption, a delay input interval must be completed. If the delay is released before timing out, the pre-emptor will not initiate time.

During pre-emptor timing any higher priority pre-emption input will override the active pre-emptor mode.

2) Interval Programs:

The following interval functions and sequence per ring shall be programmed in the pre-emptor module.

Interval 1: The minimum guaranteed green interval.

The effective start time for this interval is when the phase that is timing enters green. Therefore, if the phase was in green longer than the interval programmed time prior to initiation of pre-emption, the pre-emptor will advance to interval 3.

Interval 2: The minimum guaranteed green-pedestrian clearance interval.

The effective start time for this interval is when the phase that is timing enters pedestrian clearance. Therefore, if the phase was in pedestrian clearance longer than the interval programmed time prior to initiation of pre-emption, the pre-emptor will advance to interval 3.

Interval 3: The minimum guaranteed phase yellow clearance interval.

The effective start time for this interval is when the phase that is timing enters yellow clearance. Therefore, if the phase was in yellow clearance longer than the interval programmed time prior to initiation of pre-emption, the pre-emptor will advance to interval 4.

This interval will only be in effect if pre-emption was initiated during green or yellow. Pre-emption will terminate the green or yellow phase.

Interval 4: The minimum guaranteed overlap yellow clearance interval.

Any overlap is assigned to one ring that is timing during entry into pre-emption. The overlap will terminate when that ring starts interval.

The effective start time for this interval is when overlaps go into yellow clearance. If the overlaps have been in yellow clearance longer than the interval programmed time prior to the initiation of pre-empt, the pre-emptor will advance to interval 5.

Interval 5: The minimum guaranteed overlap all-red clearance interval.

The effective start time for this interval is when the overlaps that are going to terminate and the phase that is timing are in red. This interval will stay in effect until all the overlaps that are going to terminate, and the phase that is timing has been in red for the programmed all-red time. The pre-emptor then will advance to interval 6.

If there is no track clearance phase assigned to a ring, that ring will advance to interval 9.

Interval 6: The track clearance green interval.

This interval will time the assigned track clearance green programmed time, and upon completion, the ring will advance to interval 7.

Interval 7: The track clearance yellow interval.

This interval will time the assigned track clearance yellow programmed time. When the timing is complete, the ring will advance to interval 8.

Interval 8: the track clearance all red interval.

This interval will time the assigned track clearance all red programmed time. When the timing is complete, the ring will advance to interval 9.

Interval 9: The hold/lock interval.

When both rings of the pre-emptor sequence have reached interval 9, the pre-emptor will be advanced to interval A.

Interval A: The duration passage interval.

This interval will time the completion of the programmed duration time. The duration time will start timing when the pre-emption sequence is started. Interval A will insure that the pre-emption sequence will not terminate until programmed time after initiation of pre-emption, regardless of the phases and intervals in effect during initiation of pre-emption or the timing of intervals preceding interval A.

The phase assigned for each ring shall operate as a hold phase. The options of "ped indications active" and "hold flash" take effect during this interval.

Interval B: The hold/passage interval.

The hold time will start timing when pre-emption interval A starts. Interval B will insure a minimum time in the passage movement before pre-emption will be permitted to terminate. The interval will terminate only when the programmed time is complete and the pre-emption input is non-active, after which the interval will be set to C.

The hold phases, "ped indications active" and "hold flash" shall be applied during interval B.

Interval C: The hold/passage yellow clearance interval.

At the completion of the hold/passage interval, the hold clearance yellow will time unless:

- (1) There are no exit phases. The pre-emptor will be non-active, and exit as soon as interval B is complete.
- (2) The pre-empt call returns active. The pre-emptor will go back to interval B.

When the hold/passage yellow clearance timing is complete, the interval will advance to interval D.

Interval D: The hold/clearance all-red clearance interval.

If the pre-emption call returns, the pre-emptor will go back to interval B.

When the hold/passage all red clearance timing is complete, the interval will advance to interval E.

Interval E: The exit lock interval for the pre-emptor.

When both pre-emption rings get to interval E, the pre-emptor will exit the pre-emption sequence.

3) Pre-emptor Flash:

The Type MPS controller pre-emption module flash can be initiated in the following ways:

- (a) Hold Flash
- (b) Power up with pre-emption
- (c) External start with pre-emption
- (d) Sum check bad
- (e) Power up/external start with illegal phases
- (f) Illegal controller software valve.

The pre-emptor flash control output shall be true (low) during pre-emptor flash.

The controller signal output drivers will flash red if they are not assigned as a hold phase. The output shall flash yellow if assigned as a hold phase.

The required preemption intervals shall be programmed for single track or dual track clearance as shown on the plans.

734-2.03 Control Cabinets:

(A) General:

The control cabinets covered in this section shall be used to house all traffic pre-timed and actuated signal controller assemblies and shall include intersection controller cabinets and auxiliary controller cabinets. The cabinets shall be wired for all additional future phases and all associated equipment for the future phases shall be furnished and installed.

Cabinets shall be wired and tested by the controller manufacturer or a representative designated by the controller manufacturer. The cabinet wiring shall be covered by the controller manufacturer's warranty.

The following cabinet types shall be supplied when specified on the plans. The cabinets shall be constructed according to the Traffic Signal and Highway Lighting Standard Drawings:

Type I	Pedestal Base Cabinet
Type I	Controller Cabinet

Type II Controller Cabinet

Type III Controller Cabinet

Type IV Controller Cabinet

Type V Controller Cabinet

Auxiliary controller cabinets shall be either a Type I controller cabinet for pole mounting or a Type II Load Center Cabinet for foundation mounting.

The controller cabinet housings shall be of a NEMA 3 weather resistant construction. The steel cabinet housing and accessories shall be treated on the inside and outside with one coat of primer paint and painted with two coats of aluminum paint in accordance with Section 1002. Cabinets shall have continuous welded seams on all outside seams.

The steel fabricated cabinet housings shall be constructed with No. 14 copper bearing sheet steel.

The aluminum fabricated cabinet housings shall be constructed with No. 10 gage welded sheet aluminum. The cabinet finish shall be clean and not painted.

(B) Hardware:

(1) Doors:

The doors shall have a neoprene gasket around the perimeters of each door frame. The door hinge pins shall be stainless steel. The main controller cabinet door, except the Type I, shall have a two-position steel-bar type door stop.

The main doors of the Types III, IV, and V controller cabinets shall be secured by a three-point locking device.

(2) Locks:

The main doors of controller cabinets shall have a standard traffic signal self-locking tumbler lock. The three-point door latch cam shall be steel.

The pedestal base cabinet doors and the police panel doors shall have a standard police-type lock. The police-type lock key shaft shall be a minimum of 1-3/4 inch in length.

A minimum of two keys per lock shall be furnished with each cabinet.

(3) Shelves:

Each controller cabinet shall be furnished with metal shelves capable of supporting all shelf mounted equipment without bending or sagging.

The shelves shall not sag or restrict the free flow of air. The cabinets shall contain adjustable support brackets. For NEMA controllers the following shelf heights shall be furnished with the delivered cabinet:

- (a) A minimum shelf height of 14 inches shall be provided for two-phase controllers.
- (b) A minimum shelf height of 15 inches shall be provided for four-phase and eight-phase NEMA controllers, and pre-timed controllers.

(C) Cabinet Accessories:

The following accessories shall be provided with each controller cabinet as specified herein:

(1) Cabinet Light:

The Types II and III controller cabinets shall contain a minimum 15-inch fluorescent light fixture and lamp. The Types IV and V controller cabinets shall contain a minimum 18-inch fluorescent light fixture and lamp. The fixture shall be mounted on the inside top of the cabinet near the front edge of the roof so that the front panels of the control equipment will be illuminated.

A door-actuated, refrigerator-type, normally closed, durable push-button type switch shall automatically turn the light fixture on and off when the door is opened and closed.

(2) Switches:

The switches described in this section shall be provided for all solid state digital controller cabinets. Each switch shall be a commercial grade switch properly rated for the circuits they control. Each switch shall be individually labeled to identify its function. The label shall be an engraved laminated plastic legend plate or a permanently printed metallic legend plate.

The following switches shall be mounted on the cabinet switch panel inside the controller cabinet housing:

- (a) Indicator Lamp Control: A door actuated switch that shall operate with any controller unit which activates the controller indicator lamps.
- (b) Auto/Flash Switch: A toggle switch to transfer to flashing operation. During the flash operation the AC power shall be disconnected from the controller.
- (c) Detector Call Test Switches (including Pre-Timed-Cabinets): A test switch shall be furnished to simulate a vehicle and pedestrian actuation. Each switch shall be a momentary contact push button. The metering controller shall have test switches for each detector input shown on the plans. Each switch shall be labeled to identify its function and phase.

- (d) Pre-emptor Switch: When a traffic control pre-emptor is specified on the plans, it shall be controlled by a two-position toggle switch. The "Test" position shall manually turn on the pre-emption operation. The "Auto" position shall be for automatic external control of the pre-emptor.
- (e) Stop Time Switch: A separate two-position stop time toggle switch shall be provided to permit stop timing/automatic mode of the controller's stop time function. The two positions shall be labeled "stop time - auto". When required, other special function switches shall be furnished. Such switches shall be of the proper voltage and current rating to perform the function as specified. The following switches shall be mounted in the police panel:
- (f) Main Switch: This shall be the main on/off switch to control the AC power to the signal controller assembly. The switch shall be properly sized for the amperage of the equipment.
- (g) Auto/Flash Switch: shall be a toggle switch to transfer from automatic control to flashing operation. During the flash operation the AC power shall be maintained to the controller.
- (h) Photo-Off-Manual Switch: Lighting contactors shall be controlled by a three-position double-pole, double-throw switch. The "Photo" position shall place the contactor under the control of the photoelectric cell unit. The "Off" position shall disconnect the contactor's coil from the photoelectric control. The "Manual" position shall activate the contactor and turn on the intersection lighting.

(3) Convenience Outlet:

A 120-volt AC, 15-Amp. NEMA 5-15 G.F.I. convenience duplex outlet shall be mounted in each cabinet for energizing test equipment or tools. The outlet shall be fuse protected.

(D) Cabinet Ventilation Equipment:

Cabinet Fan and Filters:

Controller cabinets containing solid state electronic equipment shall be ventilated by means of a 120-volt AC, 60-hertz, tube-axial compact type fan. The fan's free delivery air flow shall be not less than 100 cubic feet per minute.

The fan housing shall be approximately four inches square by 1-1/2 inches deep.

The magnetic field of the fan motor shall not affect the performance of the control equipment.

The fan bearings shall operate freely within the environmental standards specified herein.

The fan unit shall not crack, creep, warp, or have bearing failure within a five-year rated duty cycle. The maximum noise level shall be 40 decibels. The fan unit shall be corrosion resistant.

The cabinet fan shall be controlled by an adjustable snap action thermostat. The thermostat's turn-on setting shall be adjustable from 90 to 120 degrees F. The fan shall run until the cabinet temperature decreases to approximately 20 degrees F below the turn-on temperature setting. The fan shall be fused.

The cabinet fan assembly shall be mounted either inside the control cabinet or inside a rainproof housing on top of the control cabinet.

The cabinet shall have louvered air inlets in the lower portion of the main door. A standard furnace filter shall be mounted behind all the louvered air inlets.

The air outlets shall be screened on the exhaust side of the fan unit. The cabinet shall have a dust resistant air outlet baffle well secured and removable in the top of the cabinet.

Auxiliary cabinets containing solid state electronic equipment shall use fan units with a free delivery air flow of not less than 100 cubic feet per minute. The fan unit shall be approximately 3-1/2 inches square. All other fan characteristics shall be as described above in this section.

(E) Electrical Devices:

(1) Legend Plates:

An engraved laminated plastic legend plate or a permanently printed metallic legend plate shall be provided inside the control cabinet for each control device, connector cable, connector, and fuse mounted in the cabinet. Each control device shall be labeled to identify the type of device and its connector number. Each fuse shall be labeled to identify its rating and circuit function.

(2) Power Panel:

The power supplied to the controller cabinet shall be 120-volt AC, two-wire, 60-hertz, single-phase service unless otherwise specified.

The power leg to the controller and the signal load circuits shall be protected by a single-pole, 120-volt AC, circuit breaker. The breaker shall have a 10,000 ampere interruption rating, a trip indicator, and shall be the bolt-on type. The ampere rating shall be properly sized for the traffic signal intersection's load.

The neutral service leg shall be connected to the AC neutral buss.

The 120-volt AC intersection lighting control circuit, and the convenience outlet shall not be connected to the same service leg to which the controller's power supply is connected.

The lighting load shall be 240-volt AC unless otherwise specified.

(3) Radio Interference Suppressor:

Each control cabinet shall be equipped with a single radio interference suppressor (RIS) of sufficient ampere rating to handle the load requirements. The RIS shall be installed at the input power point. It shall minimize interference in both the broadcast and the aircraft frequencies, and shall provide a minimum attenuation of 50 decibels over a frequency range of from 200 kilohertz to 75 megahertz, when used in connection with normal installations.

The RIS shall be hermetically sealed in a substantial metal case which shall be filled with a suitable insulating compound. The terminals shall be nickel-plated 10/24 brass studs of sufficient external length to provide space to connect on No. 8 AWG wires, and shall be so mounted that they cannot be turned in the case. Ungrounded terminals shall be properly insulated from each other, and shall maintain a surface leakage distance of not less than 1/4 inch between any exposed current conductor and any other metallic parts. The terminals shall have an insulation factor of 100-200 megohms dependent upon external circuit conditions. The RIS shall not be rated less than 50 amperes.

The RIS shall be designed for operation on 115-volt AC \pm 10 percent, 60-hertz., single-phase circuits, and shall meet the standards of UL and the Radio Manufacturers Association.

(4) Surge Protector:

Each controller cabinet shall be provided with a 350-volt surge protector at the input power point. The surge protector shall reduce the effects of power line voltage transients and shall have ratings as follows:

Impulse Breakdown	less than 1,000 volts in less than 0.1 microseconds at 10 kilovolts per microsecond
Standby Current	less than 1.0 milliamperes
Striking Voltage	350 volts D.C.

Shall be capable of withstanding 15 pulses of peak current each of which will rise in 8.0 microseconds to one-half the peak voltage at three-minute intervals. The peak current rating shall be 20,000 amperes.

(5) Inductive Suppressors:

Each 120-volt AC circuit that serves an inductive device, such as a fan motor, cabinet light, or a mechanical relay, shall have a suppressor to protect the controller's solid state devices from excessive voltage surges. Such suppressors shall be in addition to the surge protector at the main input power point.

(F) Cabinet Wiring Standards:

(1) Conductors:

All conductors used in controller cabinet wiring shall be No. 22 or larger, with a minimum of 19 copper strands. Conductors shall conform to Military Specification MIL-W-16878D, Type B or better. The insulation shall have a minimum thickness of 10 mils and shall be nylon-jacketed polyvinyl chloride or shall be irradiated cross-link polyvinyl chloride, polyhalocarbon, or polychlor-alkene.

(2) Lead-in Wires and Cable:

Lead-in wires, from the loop detector field terminals in the cabinet to the amplifier unit inside the cabinet, shall conform to one of the following:

A twisted pair of No. 22, or larger, conductors.

A cable containing two No. 22, or larger, conductors with each conductor insulated with either (1) a minimum of 10 mils of polyvinyl chloride and two mils of nylon, or (2) a minimum of 14 mils of polyethylene or polypropylene. The conductors shall be twisted pairs with three to six turns per foot. The cable shall be provided with a polyethylene or polyvinyl chloride outer jacket with a minimum thickness of 20 mils, or with a chrome vinyl outer jacket with a minimum thickness of 25 mils.

All conductors used in controller cabinet wiring shall conform to the following color code requirements:

The AC common conductors shall be identified by a continuous white or natural gray.

The chassis ground conductors shall be identified by a continuous green color with one or more yellow stripes.

The non-grounded conductors shall be identified by any color not specified above.

(3) Load Switch and Flasher Wiring:

Each of the load switch outputs (120-volt AC) and the flash transfer relay load base terminals shall be hard-wired with a minimum No. 14 copper conductor with a 90 °C rated jacket, or No. 16 copper conductor with a 105 °C rated jacket.

The 120-volt AC load switch and flash relay terminals shall be soldered to each base terminal.

(4) Signal Load Switch Buss:

The AC+ signal load switch buss shall be controlled by a signal-pole 120-volt AC mercury contactor or an auxiliary control relay. The minimum contactor size per switch buss shall be 30 amperes.

(5) Signal Load Panels:

All load switches, flashers, and flash transfer relays shall be mounted on a load bay panel or back panel assembly of the appropriate size.

Each load switch input from the controller shall be programmable on the back panel by use of removable jumpers to facilitate possible redesignation of output assignments due to future phasing requirements.

Detector amplifier modules may be mounted on the panel in lieu of a detector rack.

The signal load panel or back plane panel shall be easily removable from the cabinet for repair in the field.

All the control hardware and wiring shall be mounted and installed so as to permit the main back panel to be released and dropped for the service repairs in less than 10 minutes.

The load bay or back plane panel shall be wired to include all future signal phases and operations shown on the plans.

Printed circuit board type back panels shall only contain 0- to 24-volt DC circuits. No 120-volt AC circuits will be allowed.

(6) Pre-emption:

When specified, the controller cabinet shall include the cabinet wiring provisions for a pre-emptor controller unit and its cables.

(G) Meter Pedestal Cabinet:

Meter pedestal cabinets shall be furnished and installed in accordance with the project plans and specifications. The cabinet shall be UL listed.

The cabinet shall be 12 gage steel of tamperproof construction with piano-hinged doors and provisions for padlocks. The top and front covers of the cabinet shall be 16 gage steel.

The cabinet shall be treated on the inside and outside with one coat of primer paint and painted with two coats of aluminum paint, conforming to the requirements of Section 1002. The cabinet shall be completely wired with copper conductors to include the required circuit breakers and lighting contactors and shall be wired and equipped to handle electrical service loads as detailed on the project plans.

The service pull section shall be 4-1/2 inches deep and shall be located in back of the cabinet. An access opening in the cabinet shall be provided at the bottom of the service pull section.

Each cabinet shall have a detachable pad mount sleeve for easy installation in concrete which can be bolted to the base of the pedestal.

Electrical service shall be 120/240-volt 60-hertz, three-wire service.

(H) Cabinet-Mounted Service Enclosure:

The cabinet-mounted service enclosure shall be mounted on the back of control or load-center cabinets to provide a combination of metered and unmetered service for traffic signals and highway lighting, respectively. The service enclosure shall provide for both metered and unmetered load circuits. The enclosure shall be rated for 100-ampere continuous service and shall comply with the requirements of the serving utility company.

The cabinet-mounted service enclosure shall be fabricated from 14 gage zinc-coated steel with tamperproof construction. The enclosure shall be a NEMA 3R rainproof type with provisions for padlocks.

The enclosure shall have factory installed breakers, sockets and other components and shall be U.L. listed. The installed conductors shall be copper of the size and type to conform to the NEC and U.L. requirements.

The enclosure shall be finished with one coat of primer paint and two coats of aluminum paint conforming to the requirements of Section 1002.

(I) Cabinet Foundations:

Concrete for cabinet foundations shall be 3,000-pound per square inch Class S concrete.

734-2.04 Auxiliary Control Equipment:

The auxiliary equipment described in this section shall be supplied and installed as required inside the controller cabinet.

All auxiliary equipment shall conform to current published NEMA Standards pertaining to that device.

(A) Flasher Control Assembly:

The flasher control equipment shall consist of a complete electrical assembly which shall provide flashing traffic signals by enabling flash relays when the auto/flash switch or conflict monitor is activated. The relays shall be the flash load relay type as specified herein.

(B) Solid State Flashers:

The flasher unit shall be a solid state NEMA-type flasher. All flashers for signalized intersections, pole flashers, and overhead flashers, shall be the dual circuit type.

All the flashers shall be constructed of replaceable, molded relay modules. Each relay module shall have the specified ampere capacity and shall operate with zero point switching.

The flasher shall turn on within five degrees of the zero voltage point of the line sinusoid and shall turn off within five degrees of the zero current point of the line sinusoid. The flashing rate shall be 55 to 60 flashes per minute with a 50 percent duty cycle.

Solid state flashers shall be one of the following types:

- Type 1 20 amperes per circuit, single circuit
- Type 2 20 amperes per circuit, dual circuit

The flashers shall interconnect with a six-pin Cinch-Jones, S-406-SB socket. The flasher shall either have a support bracket or shall be mounted in a rack frame.

(C) Solid State Load Switches:

Load switches shall meet the requirements of NEMA for three-circuit load switches.

Each load switch shall contain three individually replaceable, solid state relay modules. Each relay module shall utilize optical isolation between the input and the output. The relay module shall have the following functions and terminal assignments:

Terminal	Function
1	120 volt AC Output
2	120 volt AC Line
3	+12 to 28 volts DC
4	Sequence Input (Ground)

Each panel of load switches shall either be rack mounted or shall have a switch support bracket extending across the entire length of the switch panel.

The load switch unit shall have three indicators to designate when the AC output circuits are activated. Each indicator shall monitor the outputs and shall be labeled top to bottom "R" Red, "Y" Yellow, and "G" Green, on the front panel of the load switch unit.

(D) Flash Load Relays:

Flash load relays shall be for the purpose of providing special circuitry or operational requirements. The relays shall be the double-pole, double-throw type.

Flash relays shall interconnect with a Cinch-Jones type eight-pin socket or an approved equal. The relay shall be covered with a clear dust cover which shall be secured to the relay base with a fastening device.

The relay contact points shall be of fine silver or silver alloy, or a superior alternate material, and shall be capable of carrying a load of 20 amperes per contact unless otherwise specified at 120 volts AC.

The relay shall show no failure while making, carrying, and breaking a 10-ampere, 120-volt, traffic signal lamp load through 10,000 cycles at the rate of 10 cycles per minute and a 50 percent duty cycle. Each relay shall be capable of making, breaking, and carrying all the current for a 1,000-watt tungsten lamp load without burning, pitting, or otherwise failing for at least one million operations.

The relay shall be electrically and mechanically operative after a momentary current of 100 amperes at 120 volts is applied to the set of closed contacts at least five times with a minimum of two minutes between applications of current. The relay shall not break down or flash over while carrying a load of 10 amperes at 120 volts for at least 50 cycles at the rate of five cycles per minute. The duty cycle shall be 50 percent on and 50 percent off.

The relay shall withstand 1,500 volts at 60 hertz between insulated parts and between current carrying parts and grounded or non-current carrying parts.

(E) Auxiliary Control Relays:

These types of relays shall be utilized in circuits to provide special operations.

Auxiliary control relays shall have a pin-type connector on the base. The relay shall be removable without the use of tools.

The relay shall be covered with a removable dust cover. The relay coil shall be rated at 120-volts AC, 28-volts AC/DC, or 12-volts AC/DC as required. The contacts shall be single-pole or double-pole. The number of contacts shall be as required by the relay's operational functions. The contacts shall be properly rated for the circuit load and shall be constructed of gold- and/or silver-plated material.

(F) Conflict Monitors:

The conflict monitor shall conform to the current NEMA specifications.

Fully programmable monitors shall be programmed with soldered wire jumpers on a NEMA interchangeable programming card. Jumpered channels shall represent nonconflicting phases. Non-jumpered channels shall be in conflict with any other channel.

When a malfunctioning monitor is replaced in the field, the replacement monitor shall be field programmable without the use of tools.

The jumper numerical sequence shall be standard NEMA matrix.

The monitor shall have an active indicator for each channel.

(G) Detector Amplifiers:

(1) General:

The correct type and quantity of detector amplifiers shall be furnished as specified herein, as required on the plans. Unless otherwise specified, all detector amplifiers shall be rack mounted or mounted on a load bay panel with support brackets. Each rack position shall be labeled.

Each detector card shall be the edge connected type. The detector edge connector shall be a 44-pin double read-out contact. The connector shall have 0.128-inch diameter mounting holes on each end, MIL-M-14 insulation material, and MIL-C-21097 contacts.

The edge connector terminals, for the specified type of detector amplifier, shall be wired as specified herein. All of the detector channel inputs and outputs, including those channels specified for future use, shall be wired from the mounting rack to the tie points and the field terminals of the controller cabinet.

Each amplifier rack assembly shall include one power supply card per each set of four detector amplifier modules. The required number of power supply cards shall be furnished with each rack assembly which shall include the quantity of power supply cards for future phases shown on the plans and one spare edge connector.

The required quantity of amplifier modules, including those required for future phases shown on the plans, and one spare edge connector shall be furnished with each control cabinet assembly.

The amplifier rack positions shall be mechanically and electrically interchangeable such that amplifier modules of different manufacturers can be connected into any amplifier module positions. The rack spacing shall be for NEMA 2.31-inch wide front panels on all card rack units.

(2) Detector Amplifier Power Supply:

A rack-mounted 24-volt DC power supply shall be furnished with each controller cabinet assembly with more than two amplifier modules. Each detector amplifier module shall have a 24-volt DC power supply. The power supply shall have four power outputs each fused and rated at 300 milliamps and 24 volts DC and a maximum ripple voltage of 2.2 volts peak to peak. All 120-volt AC circuits shall have fused inputs.

The power supply PIN numbers and functions shall be as designated in the following table:

Standard Input and Output Functions for Vehicle Detection Assembly			
Power Supply			
Pin No.	Function	Pin No.	Function
A	Output Logic Ground	1	(Redundant Side)
B	Output 1 (+24-volt DC)	2	
C		3	
D		4	
E		5	
F		6	
H		7	

Standard Input and Output Functions for Vehicle Detection Assembly			
Power Supply			
Pin No.	Function	Pin No.	Function
J		8	
K		9	
L	Chassis Ground	10	
M	115-volt AC (-)	11	
N	115-volt AC (+)	12	
P		13	
R		14	
S		15	
T		16	
U	Output 3 (+24-volt DC)	17	
V	Output 4 (+24-volt DC)	18	
W		19	
X		20	
Y		21	
Z		22	

(3) Loop Detector Amplifiers:

(a) General Requirements:

There shall be one amplifier channel per detector, except for the six- by six-foot detectors, unless otherwise specified.

The amplifier unit shall utilize digital solid state circuitry. The detection, frequency counting, and inductance measuring circuitry shall utilize crystal controlled MOS-LSI microelectronic circuits.

The loop detector amplifiers shall detect all licensed motor vehicles when using the loop configuration shown on the plans. The loop amplifiers shall be operational when using up to 1,000 feet of lead-in cable for a six by six-foot, three-turn, loop. Each loop detector amplifier shall detect vehicles at speeds of zero to 80 miles per hour using loop configurations ranging from: six by six feet - two-turn, six by 50 feet - one-turn, six by 70 feet - one-turn; up to six by 100 feet - one-turn loops. The smaller size six by six-foot loop sensors shall be capable of being connected to the amplifier in series and/or parallel as required.

(b) Loop Detector:

The loop detector amplifier unit shall contain two to four channels per unit.

The following types of loop detector card rack units shall be used to identify the number of detector channels and timing functions for each card:

LCR-2 Loop detector card unit with two channels.

LCR-2T	Loop detector card unit with two channels having timing functions.
LCR-4	Loop detector card unit with four channels.
LCR-4T	Loop detector card unit with four channels having functions.

No single channel amplifier shall be utilized. All loop detector card units shall be mechanically and electrically interchangeable with other card units of the same type and function from different manufacturers.

The loop modules and loop modules with timing function PIN numbers and functions shall be as designated in the following table:

Standard Input and Output Functions for Vehicle Detection Assembly			
Loop Module		2 or 4 Channel	
Pin No.	Function	Pin No.	Function
A	Logic Ground	1	Channel 1 Green
B	+ 24-volt DC IN	2	Channel 2 Green
C		3	Channel 3 Green
D	Loop 1 Twisted	4	
E	Loop 1 Pair	5	
F	Output 1 (+)	6	
H	Output 1 (-)	7	
J	Loop 2 Twisted	8	
K	Loop 2 Pair	9	
L	Chassis	10	Channel 4 Green
M		11	
N		12	
P	Loop 3 Twisted	13	
R	Loop 3 Pair	14	
S	Output 3 (+)	15	
T	Output 3 (-)	16	
U	Loop 4 Twisted	17	
V	Loop 4 Pair	18	
W	Output 2 (+)	19	
X	Output 2 (-)	20	
Y	Output 4 (+)	21	
Z	Output 4 (-)	22	

Standard loop detector racks for amplifiers not requiring timing functions shall still be wired for possible future use of timing functions (pins 1, 2, 3, and 10). The wires from these pins shall be tied to spare terminal block tie points in the cabinet.

Polarization keys shall be located at four positions:

1. Between B/2 and C/3
2. Between M/H and N/12
3. Between E/5 and F/6

(c) Amplifier Requirements:

Each amplifier channel shall have a front panel mounted indicator to provide a visual indication of each vehicle detection. The indicator shall be visible in bright sunlight from three feet directly in front of the amplifier.

The amplifier shall operate in compliance with all the requirements herein specified when connected to an inductance loop plus lead-in, of from 50 to 500 microhenries with a loop Q parameter as low as 5.0 at the amplifier's operating frequency.

Each channel's call output shall be an optically isolated solid state type. Each amplifier channel shall conform to the following requirements:

- (1) Amplifier Tuning: Each channel shall be manual or self-tuning and shall be fully operational within three minutes after power up. After a power interruption, the channel shall automatically return to normal operation.
- (2) Tracking: Each channel's circuits shall be designed so that changes due to environmental drift and applied power fluctuations shall not cause an actuation. Self-tracking shall be capable of compensating for environmental changes of up to 0.001 percent per second. The requirement must be met within two hours after initial power up. The channel shall be capable of normal operation as the input inductance is changed ± 5.0 percent from the quiescent turning point regardless of initial circuit drift.
- (3) Detection Modes: Each channel shall have a mode selection switch on the front panel which shall permit the selection of either the presence mode or the pulse mode of operation. In the pulse mode, the pulse width shall be 100 milliseconds unless otherwise specified. Each module shall have an off switch position for disabling unused channels.

(d) Special Timing Functions:

The following special timing functions shall be furnished only when specified on the plans or in the Special Provisions.

- (1) Delay Timing Function: This timing function shall delay the call output up to 15 seconds after the vehicle enters the loop sensor. The timer shall be adjustable, from 0 to 15 seconds, into no more than 1.0-second increments.
- (2) Extension Timing Function: This timing function shall carry over (i.e., extend) the call output up to seven seconds after the vehicle leaves the loop sensor. The timer shall be adjustable, from zero to seven seconds, in not more than 0.5-second increments.

When any of the above special functions are specified, then that special function shall be furnished on all channels of the same amplifier module.

(e) Amplifier Sensitivity:

Each of the amplifier channels shall have a minimum of three sensitivity settings per detection mode. The settings shall be selectable from the front panel. The highest sensitivity setting shall consistently respond to a loop inductance change of 0.02 percent. The lowest sensitivity setting shall respond to nominal loop inductance changes of from 0.15 to 0.4 percent. All modules must have sensitivities which differ by not more than ± 0.05 percent change in inductance from the nominal value chosen. A channel shall not respond to loop inductance changes less than 0.1 percent in the lowest sensitivity setting.

(f) Amplifier Response Time:

The amplifier channel response time in the lowest sensitivity setting shall be less than 20 milliseconds. For any negative inductive change which exceeds the sensitivity threshold, the channel shall output a ground true logic level within 20 milliseconds. When such inductance change is removed, the output shall become an open circuit within 20 milliseconds.

For test purposes, a negative change of inductance shall be maintained for a minimum of 100 milliseconds and a maximum of 600 milliseconds after it is applied. When the response time differences are averaged over 10 trials, the value of that average difference shall not exceed 10 milliseconds.

The response time of the detector channel for the highest sensitivity setting shall be less than 250 milliseconds for a 1.0 percent inductance change.

(g) Operating Frequency:

Each channel shall have a minimum of three operating frequencies. The frequency switch may be either on the front panel or on the circuit board. Frequency selection shall be possible without the use of tools.

(h) Detection Holding Time:

The detector channel, in the least sensitive position, shall maintain the presence detection of a vehicle for a minimum of four minutes while the vehicle is over the loop sensor and is causing an inductance change of 1.0 percent or greater.

The channel, in the highest sensitivity position, shall maintain the presence detection of a vehicle for a minimum of three minutes while the vehicle is over the loop sensor and is causing an inductance change of 0.02 percent or greater.

(i) Temperature Changes:

The operation of the amplifier shall not be affected by environmental temperature changes at the rate of 1.5 degrees F per three minutes.

(j) Interference:

Each channel shall not cause crosstalk with any other channel either within the same amplifier or within any other amplifier that is mounted in the same cabinet assembly. An amplifier channel shall not detect vehicles, moving or stopped, at distances of three feet or more from the loop perimeter to which it is connected.

(k) Lightning Protection:

Each amplifier shall have lightning protection as an integral part of its own circuitry. The protection shall enable the detector to withstand the discharge of a 10-microfarad capacitor, charged to 1,000 volts. The discharge shall be applied directly across the detector loop input pins with no loop load present.

The protection shall enable the detector to withstand the discharge of a 10-microfarad capacitor, charged to 2,000 volts. The discharge shall be applied directly across either the detector loop input pins or across either side of the loop input pins to earth ground. For this test, the detector chassis shall be grounded and the detector loop input pins shall have a 5.0-ohm dummy resistive load connected across them.

(l) Fail-safe Operation:

Each channel shall have a fail-safe design such that if the loop sensor circuit is open, the channel shall output a continuous vehicle call.

(m) Isolation Transformers:

Each loop sensor shall be coupled to the channel input by isolated transformers. The isolated input shall provide continued operation of the channel if the loop sensor in the street becomes grounded or has resistive leakage to ground.

(4) Magnetometer Detector Amplifier:

(a) General:

The magnetometer detector shall detect all licensed motor vehicles when using the probe configuration shown on the plans.

(b) Amplifier Requirements:

The amplifier shall be operational with up to 12 probes per channel, up to 2,000 feet of lead-in cable, and vehicular speeds up to 90 miles per hour. Each amplifier shall have two independent channels per card. The card shall be connectable in any detector rack position.

Solid state circuitry shall accurately measure changes in the earth's vertical magnetic field intensity caused by motor vehicles. The front panel shall have a calibration control for each channel to calibrate the amplifier for the local magnetic field strength.

Each amplifier channel shall have a front panel mounted indicator to provide a visual indication of each vehicle detection. The indicator shall be visible in bright sunlight.

Each channel call output shall be an optically isolated solid state NPN transistor with a normally open collector which shall be rated for a five-milliampere load and 0.7-volt drop maximum.

The collector shall be rated for 30-volts DC when in the off mode. Each magnetometer amplifier shall conform to the magnetometer table and the following requirements:

(c) Detection Modes:

Each channel shall permit the selection of either a presence mode or a pulse mode. Each channel shall be independent of the other channel of the amplifier. In the presence mode, the channel shall indicate the presence of a vehicle until the vehicle leaves the detection area. The indication shall then cease in 100 milliseconds. In the pulse mode, the channel shall output a single 30- to 50-millisecond pulse for each vehicle entering the detection area.

(d) Timing Functions:

Each channel shall have the following independently selectable functions. The functions shall be selectable from the front panel:

1) Inhibit Pulse Timing:

This timing function shall inhibit subsequent call outputs up to five seconds after each vehicle leaves the sensor area.

2) Extended Presence Timing:

This timing function shall carryover or extend the call output up to five seconds after each vehicle leaves the sensor area.

(e) Environmental:

The operation of the amplifier shall not be affected by nominal changes in the environment.

(f) Number of Probes:

Each amplifier channel shall operate with one to twelve sensor probes.

Standard Input and Output Functions for Vehicle Detection Assembly			
Magnetometer Module		2-Channel	
Pin No.	Function	Pin No.	Function
A	Logic Ground	1	No Connection
B	+ 24-volt DC IN	2	No Connection

Standard Input and Output Functions for Vehicle Detection Assembly			
Magnetometer Module		2-Channel	
Pin No.	Function	Pin No.	Function
C		3	No Connection
D	Probe Set 1 (White)	4	
E	Probe Set 1 (Black)	5	
F	Output 1 (+)	6	
H	Output 1 (-)	7	
J	Probe Set 1 (Red)	8	
K	Probe Set 1 (Green)	9	
L	Chassis Ground	10	No Connection
M		11	
N		12	
P	Probe Set 2 (White)	13	
T	Output 2 (-)	16	
U	Probe Set 2 (Red)	17	
V	Probe Set 2 (Green)	18	
W		19	
X		20	
Y		21	
Z		22	

A polarization key shall be located between pins R/4 and S/15.

(5) External Detector Inputs:

Each pedestrian push button, bicycle push button, or remote vehicle detector call input to the controller shall be isolated from the controller's logic ground by an auxiliary isolation relay. The isolation relay will be provided and installed by the Department. The size of the relay will be 1.6 inches wide by two inches long. The terminal strip shall be provided and wired by the contractor.

The terminal strip shall be the Type 141 with terminals in multiples of four. The size shall be 1-1/8 inches wide by 1/2 inch deep. The terminal spacing shall be 7/16 inch. The screw size shall be 6-32.

(a) Terminal Strip - A-Side:

The isolation relay shall be mounted on the A-side of the terminal strip. The A-side shall be the left hand side when the terminal strip is mounted vertically, the top side when the terminal strip is mounted vertically, or the top side when the terminal strip is mounted horizontally. Terminal No. 1 shall be the top terminal when mounted vertically or the first terminal from the right when mounted horizontally. A field terminal shall be provided to connect the detector call field inputs to the A-terminal strip.

(b) Terminal Strip - B-Side:

The B-side of the terminal shall be wired as follows for each relay required:

Terminal	Function
1	+12 or 24-volt (DC or AC)
2	Logic ground
3	(N.O.) Det. Call (for specified phase)
4	Det. call field input (for specified phase)

A power supply external to the controller shall be provided for the isolation relays. The controller power supply shall not be used for this purpose.

734-2.05 External Logic Circuit Boards:

(A) General:

External logic that is required to supplement the controller or auxiliary control units shall be on solid state, plug-in cards. The logic cards shall be designed as specified herein.

The logic cards shall be the 22-pin, edge-connector or octal-base type. The pins shall be either single- or double-sided as required.

Each card shall be keyed to prevent the improper connection of the card. The printed circuit board shall meet the requirements of NEMA TS1-14.2.3.

Power supplied from the controller's power supply shall not exceed 350 milliamperes. If more than 350 milliamperes is required, then a separate external power supply must be utilized. Such an external power supply may be either shelf-mounted or rack-mounted.

The logic circuitry shall be properly interfaced and buffered from the controller and other controller assembly equipment.

All external logic timing functions shall be digital and shall be in the required timing range. Timing entries shall be front-panel programmed without the use of tools or software and shall be accessible without the removal of the enclosure's cover. The timing shall be set by thumbwheel switches, programming pins, or digital binary (DIP) switches. The timing accuracy shall conform to NEMA TS1-2.1.11 for digital timing.

(B) Digital Time Switch:

When specified, each controller cabinet shall include a solid state digital time switch of the type specified, wired for the function detailed in the Special Provisions or plans.

The solid state digital time switch shall utilize solid state circuitry and digital timing techniques. Integrated or discrete semi-conductor devices shall be used exclusively. No electro-mechanical parts shall be employed except for the controlled circuit output relay.

The design life of all components under 24-hour-a-day operation in their electrical applications shall be not less than 10 years.

All components shall be clearly identifiable by markings on circuits boards or parts numbers on pictorial diagrams.

(1) Operational Requirements:

Each time switch shall control the required number of circuit outputs in a 24-hour period, for seven days with an omit control for any one or more of the seven days.

The time switch shall be powered by a 120-volt 60-hertz input in the temperature range between 30 and 165 degrees F. The 60-hertz line frequency shall be the time base for the clock.

(2) Time Clock Back-up:

The time switch shall have a battery back-up circuit which shall power the timer for not less than 12 continuous hours during the loss of electrical A.C. power. Battery back-up shall generate its own time base, and clock accuracy shall be within 0.02 percent. During battery back-up operation, all luminous displays and relays shall be disabled. During normal operation, the battery shall be trickle charged. The rechargeable battery system shall be an integral part of the time switch housing. The battery unit shall include an on-off control switch to permit it to be disconnected from the time switches.

(3) Programming:

Programmed time entries shall be front-panel programmed without the use of tools or software. The programming of the selectable functions and time operations shall be set by thumbwheel switches, programming pins, DIP switch, or front-panel keyboard entry.

All programming pins shall be the printed circuit receptacle, non-corrosive, turning-fork type. The pin contactor shall fit any standard 0.055-inch to 0.73-inch board. The pins shall be rated 600 volts RMS at five amperes.

The time operations shall be programmable to a one-minute increment.

(4) Displays:

The time switch shall have a digital time-of-day display; 24-hour or with A.M./P.M. indicator; in hours and minutes past midnight. There shall be a day-of-the-week-in-effect indicator.

A separate indicator shall indicate when an output circuit is active (on).

(5) Output Control Circuit:

Each output control circuit shall be a single-pole, double-throw independent relay output. The relay shall be rated not less than five amperes at 120 volts AC. The relay shall be energized when the clock program is on, and de-energized when the clock program is off.

(6) Power Supply:

The time switch shall have the 120-volt AC input fused to protect its internal circuitry. Line transients normally experienced in traffic signal controller environments shall not affect the clock accuracy herein specified. Line transient protection devices shall be provided to prevent these inaccuracies.

(7) Housing and Connector:

The entire time switch shall be completely enclosed in a dust resistant housing. The housing door shall enclose all the program switches, display and indicators.

The housing shall contain solderless lug-type terminals or a detached connector.

(8) Digital Time Switch Types:

The solid state digital time switches shall be designated in the Special Provisions or plans with the following five-position alphanumeric code. The code shall have the following meaning:

The type DTS clock shall mean the solid state digital time switch.

DTS-1-1 is a single program, single circuit.

DTS-1-3 is a single program, three-circuit.

DTS-3-3/4 is a three program, three or four-circuit as required.

The single program shall have seven on-off operations per unit and three on-off operations per circuit in a 24-hour period.

Each program shall be selectable for day omit (days 1 through 7).

The solid state time switches shall have an 11-pin octal connector. The cabinet shall have a female interface connector as shown in the following table:

Cabinet Solid State Time Switch Interface Connector	
Pin No.	Function
1	Common No. 1
2	Output No. 1 N.O.
3	Output No. 1 N.C.
4	Common No. 2
5	Output No. 2 N.O.
6	Output No. 2 N.C.
7	AC Common
8	Common No. 3
9	120-volt AC Input

Cabinet Solid State Time Switch Interface Connector	
Pin No.	Function
10	Output No. 3 N.C.
11	Output No. 3 N.O.

734-3 Construction Requirements:

734-3.01 General Requirements:

All traffic controller assembly equipment shall be furnished and installed as shown on the plans, and in accordance with the Special Provisions and these specifications. Cabinet wiring, connecting cables, support bases, and shelves shall be provided to allow for future installation and use.

734-3.02 Test Requirements:

General:

All specified traffic controller assembly items shall meet the applicable environmental and testing standards of NEMA Publication TS-1. All traffic signal controller units shall be tested by the Department's testing procedures.

734-3.03 Wiring and Grounding Requirements:

(A) Cabinet Wiring:

All cabinet wiring shall be neatly arranged and made tight by the use of wiring harnesses, cable sheaths, cable wraps, or raceways. All wires in a harness shall be laced or bound together. Harnesses shall be routed to minimize crosstalk and electrical interference.

Cabling shall be routed to prevent conductors from being in contact with metal edges. Cabling shall be arranged so that any removable assembly may be removed without disturbing conductors not associated with that assembly.

All pin assignments shall be wired to the controller cabinet terminal for future use.

The following time-base coordination wiring functions shall be provided when MPS coordination is specified to be furnished in the control cabinet.

- (1) Fully actuated controller units shall be wired to operate in non-actuated mode during coordination period.
- (2) The inside cabinet switch panel shall include a switch for coordination, and free run modes of operations. The remote free input shall be wired to a cabinet terminal tie point to permit control input from a remote input.
- (3) An auxiliary time of day (24-hour) from the MPS "D" connector output shall be wired in the cabinet to program the Max 2 Function.

(B) Conflict Monitor Wiring:

The conflict monitor unit cable shall be wired to perform the following functions:

- (1) To monitor conflicts of green, yellow and walk signal for each applicable phase.
- (2) To monitor absence of red voltage. Any phase specified for future use shall have a removable jumper so as to permit future implementation of that phase without rewiring the controller cabinet.
- (3) To monitor voltage +24-volt DC source of the controller unit and any auxiliary controller unit.
- (4) To start-delay the controller unit per NEMA Standards.
- (5) The conflict monitor cable shall have the cabinet interlock A and B wired to control cabinet tie points for future use.
- (6) The monitor input for each signal circuit shall be terminated at the furthest field terminal point, so as to monitor both the automatic and flash modes of the controller cabinet.

(C) Cabinet Grounding:

All controller cabinets and auxiliary cabinets shall have the AC common, the logic ground, and the chassis ground isolated from each other as detailed in the current NEMA Standards.

(D) Field and Tiepoint Terminal/Wiring:

(1) Controller Cabinet:

All field terminals shall be installed on a terminal support which shall be located at the rear of the lower portion of the controller cabinet and not less than five inches from the base of the cabinet.

All connectors for field terminals shall be connected to barrier-type terminal blocks. Each terminal block position shall have two No. 10-32 screw connectors (not less than 3/8 inch in length), and a removable shorting bar. Each terminal shall accommodate at least three No. 12 AWG conductors. The terminal block shall have a labeling strip for each position.

All controller assembly wiring tie points on the front side of the terminal blocks shall be the spade type. Tie points of the back side of terminal blocks shall be soldered to a lug. All crimp style connectors shall be applied with the proper tool. The tool's handles shall not open until the crimp is completed. Each terminal position shall be permanently labeled at

the terminal position. Tie points shall be required for all controller unit and auxiliary control equipment circuits.

(2) Pre-emption Cabinet Wiring:

The pre-emption cabinet shall include a load switch circuit to operate the pre-emption "No Right Turn" illuminated message signal (120-volt AC output). The field terminals shall include the following terminal positions:

- (a) To railroad (120-volt AC)
- (b) From railroad (not wired)
- (c) "No Right Turn" signal

734-3.04 Cabinet Wiring Diagrams:

Each controller cabinet assembly shall have a complete set of wiring diagrams which shall show the intersection plan, signal phasing layout, and all control device connections.

Two sets of the final wiring diagrams and a second original shall be required with delivery with each control cabinet assembly. The second original shall be a legible reproducible linen cloth, mylar film, or polyester film.

Each controller cabinet shall be furnished with a sheet metal wiring diagram print holder. The minimum size of the print holder shall be not less than nine inches wide by eight inches high by 1-1/4 inches deep, mounted inside.

734-3.05 Cabinet Foundations:

Before the concrete for cabinet foundations has set, depressions shall be made around the anchor bolts for adjustment of the cabinet leveling nuts. Cabinet foundations shall be four inches above ground level.

734-4 Method of Measurement:

Traffic signal control cabinets and meter pedestal cabinets will be measured as a unit for each controller assembly or control cabinet furnished and installed.

734-5 Basis of Payment:

The accepted quantities of traffic signal control cabinets and meter pedestal cabinets, measured as provided above, will be paid for at the contract unit price each for the type controller assembly or control cabinet designated in the bidding schedule, complete in place, which price shall be full compensation for the work described and specified herein and on the plans, including service terminal boxes, cabinet mounted service enclosures, meter sockets, breaker panels, foundations, conduit, elbows, anchor bolts, clearance pad, auxiliary signal controls, external logic modules and all other components necessary to

provide a complete functional assembly for controlling the operation and timing of traffic control signals.

SECTION 735 DETECTORS:

735-1 Description:

The work under this section shall consist of furnishing and installing vehicular and pedestrian detectors at the locations shown on the project plans and in accordance with the details shown on the plans and the requirements of these specifications.

735-2 Materials:

735-2.01 Vehicle Detectors:

(A) General:

Detectors shall conform to the minimum acceptable design and operating requirements of these specifications for detecting the presence and passage of vehicles.

(B) Loop Detectors:

The detector loop dimensions shall be as specified on the plans.

The conductors for the inductive loop detector and the loop detector lead-in cable shall be as specified in Subsection 732-2.01(B)(1).

(C) Magnetometer Detector:

Each sensing probe shall consist of a sensitive flux gate magnetometer. The magnetometer shall operate properly when excited by a triangular current of plus or minus 75 milliamps peak at five kilohertz. For a single probe in a magnetic field of 400 millioersted, the return signal shall be at least 50 millivolts RMS at 10 kilohertz. The return signal shall reverse phase when the field passes through zero.

The sensing probes shall be cylindrical having maximum dimensions of 7/8-inch diameter by four inches long. The sensing probes shall be suitable for installation in a one-inch diameter bored hole. The interconnecting four-conductor cable shall be suitable for installation in a 1/4-inch wide pavement sawed slot.

The jacket on the interconnecting cable and the casing on the sensing probe shall be an abrasion resistant polyurethane elastomer. The device shall be impervious to moisture and chemically resistant to all normal motor vehicle petroleum products.

Probe set operation shall be unaffected by temperature change, water and ice. The probes shall be operational in power line AC magnetic fields ranging to 100 millioersted peak to peak. The probe set shall be operational from -30 to +160 degrees F.

The conductor cable from the magnetometer to the adjacent pull box shall be as specified by the detector manufacturer and shall be a minimum of 50 feet in length. Each magnetometer sensor shall have one lead-in cable.

The lead-in cable from the pull box, adjacent to the magnetometer, to the control cabinet shall be unspliced and the type specified in Subsection 732-2.01.

(D) Encapsulated Loop Detector Probe:

The encapsulated loop detector probe shall detect the passage or presence of all vehicles with a standard loop detector amplifier. The dimensions of the loop detector probe shall be 0.88 inches in diameter and 3.6 inches in length. The lead-in cable shall fit in a 1/4-inch saw cut.

The loop detector probe shall operate in a temperature range from -35 to +165 degrees F with zero to 100 percent relative humidity.

The operating field intensity range shall be 200 to 1,000 millioersted with a nominal inductance of 20 microhenries plus 20 microhenries per 100 feet of cable. The nominal DC resistance shall be 0.5 ohms plus 3.2 ohms per 100 feet of probe cable.

735-2.02 Pedestrian Push-Button Detectors:

The pedestrian detector shall be a push-button switch mounted inside an approved push-button housing. The switch shall be the phenolic-enclosed SPST-type with momentary contacts. The contacts shall be rated at 15 amps and 125 volts AC. The switch shall have screw-type terminals and shall have a rated life of not less than one million operations. The switch shall operate in the normally open position.

The housing of the push-button station shall be of substantial tamper-proof construction made of cast aluminum. The assembly shall be weather-proof and so constructed that it will be impossible to receive any electrical shock under any weather conditions. The housing shall be shaped to fit the curvature of the pole to which it is attached and shall provide a rigid installation. The housing body shall contain a direct push-type actuator button, microswitch-type or approved equal. The housing cover shall contain the push-button sign as described below or as specified in the Special Provisions.

Pedestrian push-button signs shall be made with porcelain enameled 20 gage sheet steel, 9.5 inches by 12 inches in size. Corners of the sign shall be finished round for safety and neat appearance. Each hole shall be provided with a brass grommet. Instructions on the signs shall be black enameled letters or symbols on a white enamel background. The legend shall be as shown on the plans or as specified in the Special Provisions.

735-2.03 Isolated Relay Inputs:

Each pedestrian push-button or remote vehicle detector call input from an auxiliary cabinet, shall be isolated from the controller logic ground as specified in Subsection 734-2.04.

735-2.04 Saw Cut Sealant:

Saw cut sealants shall be a flexible encapsulant intended for sealing and protecting vehicle detector loop wires installed in saw cuts.

(A) Emulsified Crack Filler Sealant for Asphaltic Concrete:

Emulsified crack filler sealant may be used to seal saw cuts in asphaltic concrete and lean concrete base. The emulsified crack filler sealant shall conform to the requirements of the following table:

Emulsion (For Crack Filling)		
Tests on Emulsion	Test Method	Requirement
Viscosity: Saybolt Furol, 25 °C, seconds, range	ASTM D 244	25-150
Retained on No. 20 sieve: percent, maximum	ASTM D 244 (1)	0.10
Particle Charge:	ASTM D 244	Positive
Pumping Stability:	(2)	Passes
Settlement: 5 days, percent, maximum	ASTM D 244	5.0
Residue: percent, minimum	ASTM D 244 (3)	60.0
Test on Residue		
Viscosity: 60°C, centistokes, range	ASTM D 2170	100 - 9500
(1) Distilled water will be used instead of the two percent sodium oleate solution. (2) 450 mL of emulsion will be charged into a one-liter beaker and circulated through a gear pump (Roper 29 B 22621) having a 1/4-inch inlet and outlet. Pumping stability is acceptable if there is no significant oil separation after a circulation of 60 minutes. (3) ASTM D 244 is modified by heating a 50-gram sample to 149 °C until foaming ceases, then cooling it immediately.		

The emulsified crack sealant shall remain homogeneous within 30 days of delivery and shall be homogeneous after thorough mixing. The emulsified crack sealant shall be freeze-stabilized, and, if freezing has occurred, a homogeneous mixture shall be obtained when the material has thawed and been thoroughly mixed.

(B) One-Part Elastomeric Sealant:

One-part elastomeric sealant may be used to seal saw cuts in Portland cement concrete pavement and lean concrete base.

The sealant shall provide compressive yield strength to withstand normal vehicular traffic as well as sufficient flexibility to withstand normal movement in concrete pavements, while protecting the loop wire from moisture penetration.

The encapsulant shall be a one-part elastomeric compound requiring no mixing, measuring or application of heat prior to or during its installation.

The encapsulant shall, within its stated shelf life in original undamaged packaging, cure only in the presence of moisture. The rate of cure will, therefore, depend upon temperature and relative humidity at the time of installation. Cool dry weather will slow curing whereas warm, humid weather will accelerate curing.

The encapsulant shall be designed to enable vehicular traffic to pass over the properly filled saw cut immediately after installation without tracking or stringing of the material. The encapsulant shall form a surface skin allowing exposure to vehicular traffic within 30 minutes at 75 degrees F and completely cure to a tough, rubber-like consistency in two to seven days after installation.

Properly installed and cured encapsulant shall exhibit resistance to effects of weather, vehicular abrasion, motor oils, gasoline, anti-freeze solution, brake fluid, deicing chemicals and salt normally encountered, in such a manner that the performance of the vehicle detector loop wire is not adversely affected.

The cured encapsulant shall be temperature stable and exhibit no degradation in performance throughout the ambient pavement temperature ranges experienced within the State of Arizona.

The encapsulant shall exhibit minimal shrinkage during or after its installation, and in no manner affect the performance characteristics of the material.

The encapsulant shall be designed to permit clean-up of material and application equipment with non-flammable solvents such as 1,1,1 trichloroethane or Scotch-Grip Brand Solvent No. 4 (prior to curing of encapsulant). Should any encapsulant material be allowed to cure in the application nozzle, it shall be able to be pulled out as a solid plug.

The encapsulant shall have a minimum 12-month shelf life in undamaged original containers when stored in a cool, dry environment.

The encapsulant shall be designed for roadway installation when the surface temperature is between 40 and 140 degrees F.

The encapsulant shall have the following physical properties in its uncured and cured states.

Uncured (Wet) Encapsulant		
Property	Requirement	Test Procedures
Weight	10.1 ± 0.3 pounds/gallon	A. Weight/Gallon
Total Solids by Weight	75 – 85%	B. Determination of Non-Volatile Content
Viscosity	10,000 - 85,000 centipoise	C. Dynamic Viscosity
Drying Time	Touch: 24 hrs. maximum Complete: 30 hrs. max.	D. Tack-Free Time

Cured Encapsulant		
Property	Requirement	Test Procedure
Hardness (Indentation)	65 - 85	E. Rex hardness
Tensile Strength	500 psi minimum	F. Tensile & Elongation
Elongation	300% minimum	

(C) Hot Applied Rubberized Sealant:

Hot applied rubberized sealant may be used to seal saw cuts in asphaltic concrete and in lean concrete base. It shall be suitable for use as a sealant for traffic loop saw cuts and be nontracking under traffic. At application temperatures, the traffic loop sealant shall be a thin, free flowing fluid which penetrates saw cuts and self-levels permitting uniform application. The sealant shall be melted and applied to pavements using a pressure feed melter unit. Pour pot application is not acceptable. The sealant shall be a relatively stiff sealant but shall remain flexible at low pavement surface temperatures. The test results shall conform to the following specifications for the loop detector sealant.

Test	Specification
Penetration: 125 °F, 50g, 5s	50 maximum
Penetration: 77 °F, 100g, 5s	10 - 25
Softening Point:	210 °F minimum
Ductility: 77 °F	15 cm minimum
Mandrel Bend: 0 °F, 90° Arc, 10s, 3/4 inch diameter	Pass 2 of 3
Recommended Pour Temp:	380 °F
Safe Heating Temp:	420 °F
Brookfield Viscosity: 400 °F	7,500 centipoise max.
Unit Weight:	8.5 pounds per gallon
Coverage; 1/2 by 1/2 inch crack	11.0 pounds per 100 feet

735-3 Construction Requirements:

735-3.01 Detector Installation:

(A) General:

Detectors shall be installed as shown on the project plans, as shown in the Standard Drawings, and as directed by the Engineer. The installation of the detectors shall be such that the operation shall not be affected by temperature changes, water, ice, rain, snow, chemicals, or electromagnetic noise.

(B) Hold Down Tabs:

Hold down tabs shall be installed in the saw cut on top of the wire every two feet. The tabs shall be installed after the loop wire installation and prior to the sealant installation. The

tabs shall be individual sections of PVC tubing one inch in length which shall be bent and wedged tightly into the saw cut channel.

(C) Saw Cut Sealants:

Saw cuts shall be sealed with an approved sealant. All slots cut in the pavement shall be blown out and dried before installing conductors. After the conductors are installed in the slots, the slots shall be filled to within 1/8 inch of the pavement surface with the sealant. Before the sealant sets up, the surplus sealant shall be removed from the road surface without the use of solvents. The handling of the sealant and the filling of the saw cut shall be in accordance with the directions of the manufacturer. Sand blotter shall be applied as directed by the Engineer.

(D) Splices:

The detector sensor conductors shall be spliced to the detector lead-in cable in the adjacent pull box. Detector lead-in cables shall run continuous and unspliced to the controller cabinet. Detector lead-in cables shall not be spliced without the approval of the Engineer.

All detector wire splices shall be soldered using resin-core solder with 60 percent tin and 40 percent lead. The splices shall be sealed from moisture with self encapsulating fit caps. When heated, the fit cap's inner thermoplastic adhesive shall temporarily melt and the fit cap's outer wall shall shrink. A weather proof bond shall form with a dielectric strength of 500 volts per mil, and water absorption shall be less than 6.5 percent. The detector lead-in cable shield shall only be grounded on one end in the control cabinet.

(E) Detector Loop Installation Field Tests:

Before and after the saw cut sealant has been installed, the contractor shall perform an insulation resistance-to-ground test. The insulation resistance-to-ground shall be at least 50 megohms when measured at a voltage between 400 and 600 volts D.C.

Any loop detector that does not meet the above requirement or cannot be tuned to the Engineer's satisfaction shall be replaced by the contractor at no cost to the Department.

(F) Magnetometer Field Tests:

If the probe locations shown on the project plans occur in the following areas, the contractor shall request the Department to perform a magnetic field analyzer test:

Within 24 inches of a metal object such as a manhole cover or large pipe.

Within 24 inches of railroad tracks.

Within tunnels, iron structures, or in bridge decks.

After the above analyzer test has been performed, the Contractor shall install the probes where directed by the Engineer.

735-3.02 Blank

735-4 Method of Measurement:

Loop detectors, magnetometer detectors and pedestrian detectors will be measured as a unit for each type of detector furnished and installed.

735-5 Basis of Payment:

Loop detectors, magnetometer detectors and pedestrian detectors, measured as provided above, will be paid for at the contract unit price each for the type detector designated in the bidding schedule, complete in place, which price shall be full compensation for the work described and specified herein and on the plans.

SECTION 736 HIGHWAY AND SIGN LIGHTING:

736-1 Description:

The work under this section shall consist of furnishing and installing or modifying highway lighting systems or sign illumination systems at the locations shown on the project plans and in accordance with the details shown on the plans and the requirements of these specifications.

The work as described above shall include furnishing and installing all materials and equipment designated on the project plans necessary for the installation of future systems.

736-2 Materials:

736-2.01 Highway Lighting Materials:

Highway lighting materials shall conform to the requirements of this section and be of the type and size specified. All lighting fixtures shall be supplied complete with lamps.

(A) Horizontally-Mounted High Pressure Sodium Luminaires:

The luminaires shall be 150-, 250-, or 400-watt, as specified, high pressure sodium luminaires of the horizontal burning type. The housing, together with the reflector, shall be of sufficient size to properly utilize the high pressure sodium lamps designated. The light distribution shall be Type III medium cutoff unless otherwise specified and shall conform to the Illumination Engineering Society (IES) standards.

Each luminaire shall be furnished with an instruction sheet which clearly shows installation procedures and instructions for adjusting the lamp socket. This instruction sheet shall include complete information on all socket positions and the IES light distribution produced from each setting.

(1) Luminaire Housing:

The luminaire housing shall be fabricated from a noncorrosive material. The lower portion of the luminaire shall be composed of two parts. One part shall contain the 90-degree cut-off type flat glass optical assembly, and the other part shall be the ballast module door. The ballast module door shall contain all the major electrical components and shall be capable of being lowered after loosening a single stainless steel captive screw. The ballast shall be pre-wired to the lamp socket and terminal board. The ballast module door assembly shall be removable and replaceable by the use of quick disconnect plugs. The optical assembly holder shall have an automatic latch with a safety catch on the house side. The holder shall be forced upward at the street side by spring pressure against the gasket seal when in the closed and latched position. The luminaire shall have a slipfitter for mounting on a two-inch nominal mast arm tenon and shall be adjustable for leveling plus or minus three degrees from the horizontal. The optical assemblies and housing size for the 150- and 250-watt luminaires shall be the same size as is used for 400-watt luminaires.

(2) Optical Assembly and Gaskets:

The optical assembly shall incorporate a snap-on, high specular, anodized reflector and shall contain a filter which effectively absorbs gaseous contaminants or particulate matter.

The flat glass of the optical assembly shall be manufactured of high quality, heat resistant glass.

A gasket of an approved neoprene material that will maintain a watertight and dust-tight seal throughout the temperature ranges inherent with high intensity discharge lamps, shall be securely fastened to the reflector. The gasket between the lamp socket and the reflector shall be polyester fiber that will maintain a dust-tight seal throughout the above specified temperature ranges.

The lamp socket shall be of rugged, high grade porcelain securely mounted to a support bracket which is adjustable in both the vertical and the horizontal directions. Each adjustment shall be clearly and permanently coded for each light distribution setting. The coding shall directly relate to the instruction sheet furnished with each luminaire.

(3) Ballast:

The ballast shall be a three-winding lag-type magnetic regulator and shall be capable of starting lamps at 40 degrees F and operating the lamps within the limits specified by the lamp manufacturer. The starting amperes shall be less than operating amperes. The ballast shall provide the lamp voltage shown in the lamp table of Subsection 736-2.01(C). The ballast shall be prewired to the lamp socket and terminal board. Ballast shall be rated to the circuit voltage and size of the lamp specified. The ballast shall be capable of operating for a six month period during a short circuit failure, lamp open, or end of life cycle without any measurable deterioration to the ballast.

The ballast shall have the following characteristics:

	Initial (Percent)	End Of Lamp Life (Percent)
Power Factor	99	90
Lamp Regulation Spread	14	18
Input Voltage Dip Tolerance	60	30
Lamp Wattage Regulation	0.8 percent for each one percent of line voltage	
Line Voltage Variation	± 10	

(B) Vertically-Mounted High Pressure Sodium Luminaires:

The 250- or 400-watt vertical luminaires specified on the plans shall be a pole-top-type fixture and shall be mounted with a vertical slipfitter. The vertical luminaires shall be an approved pole-top fixture, designed to illuminate roadways from offsets of up to 50 feet.

The luminaire shall be an enclosed design with an optical system consisting of a single-piece hydroformed, specular, anodic finished, aluminum reflector and a prismatic borosilicate, thermal resistant glass refractor.

The lamp socket shall be permanently attached to the reflector to assure correct lamp positioning at all times, and shall be provided with a quick disconnect for easy removal of the reflector socket assembly.

(1) Luminaire Housing:

The housing of the luminaire shall be cast aluminum with a baked enamel finish and shall consist of a housing containing the reflector and electrical equipment, and a refractor housing which shall be securely attached to the main housing by means of two stainless steel top hinges and two trigger actuated bottom latches. The refractor housing shall be readily removable for luminaire servicing.

(2) Gaskets:

Seals and/or gaskets shall be provided at all critical points to prevent entry of contaminants. A breathing seal, polyester fiber gasket shall be provided at the lower juncture of the housings to filter air entering the fixture. Neoprene gasketing shall be used at all other junctures between the housings.

(3) Adjusting and Aiming Device:

The luminaire shall be equipped with a vertical slipfitter and a leveling and aiming adjustment assembly for rapid and versatile field installation and adjustment. The slipfitter assembly may be manufactured from cast steel or have a galvanized steel pipe and yoke assembly. The galvanized steel pipe and yoke assembly shall have a weather-tight wiring box with a No. 14 AWG, three-conductor, Type ST, 105 °C ballast cord. The slipfitter shall accept pole tenons from 2-3/8inches to 3 inches outside diameter. The assembly shall provide a horizontal leveling adjustment of plus or minus five degrees and a vertical angle adjustment of 15 degrees above and below a standard luminaire angle position of 45

degrees. The reference line for measuring vertical angles shall be the vertical axis of the pole looking downward from the pole top.

Each luminaire shall be furnished with an instruction sheet which clearly shows installation procedures and instructions for proper luminaire tilt angle and aiming adjustments.

(4) Ballast Module:

The ballast and all major electrical components shall be combined into one pad-type unit, which shall be removable from the luminaire and replaceable by use of any easy operating latching device and a quick disconnect electrical plug.

(5) High Pressure Sodium Ballast Operation:

The ballast shall be rated to the circuit voltage and size of the lamp specified. The regulator-type ballast shall be capable of starting the lamp at -20 degrees F and shall deliver the required lamp watts within plus or minus five percent with ± 10 percent variation in applied voltage. At rated line voltage, the ballast shall have a minimum power factor at end of life of 90 percent. The starting amperes shall be less than the operating amperes. The ballast shall provide the lamp voltage shown in the lamp table of Subsection 736-2.01(C). The ballast shall be prewired to the lamp socket and terminal board. The electrical connections shall be made by means of pre-wired quick disconnect plugs. The ballast shall be capable of operating for a six month period during a short circuit failure, lamp open, or end of life cycle without any measurable deterioration to the ballast.

(6) Uplight Shield:

The uplight shield shall be 0.100-inch aluminum sheet material mounted with a minimum of nine stainless steel screws. The shield's inside and outside surfaces shall have a polyester powder painted finish. The shield shall be the same color as the luminaire. It shall be configured to provide less than one percent uplight above the horizontal, as shown by independent test lab reports. The equivalent projected area shall be less than or equal to 4.15 square feet. The contractor shall furnish the Engineer with certified copies of the results of the independent test lab reports.

The entire luminaire shall have passed a 100,000-cycle, 2.25-g vibration test under normal operating conditions without mechanical failure of any part including the pole and foundation. All components shall be of non-corrosive material or have positive corrosion protection.

(C) Lamps:

The lamps shall be universal burning, clear, high pressure sodium type. Each lamp shall be clearly and permanently marked, giving the wattage and the American Standard Association number or the manufacturer's reference number. Lamps of the wattage specified shall conform to the following:

Wattage	Lamp Voltage	Min. Initial Lumens	Rated Life (hours)
150	55	16,000	24,000
250	100	30,000	24,000
310	100	37,000	24,000
400	100	50,000	24,000

(D) Lighting Controls:

(1) Photo Electric Controls:

The photo electric controls, hereinafter referred to as PEC, shall have a supply voltage rating of 105 to 285 volts AC, 60 hertz.

The nominal dimensions shall be 3.078 inches outside diameter and 2.219 inches maximum height. The operating temperature range shall be from -65 to +158 degrees F with zero to 100 percent relative humidity. A time delay shall be incorporated into the circuit to prevent the lights from being turned off at night by transient lights which might be focused on the control. The PEC shall be a conventional glass faced, hermetically sealed cell.

When the north sky illumination in the area falls to the pre-set value, the lighting load shall be turned on.

A switch to permit manual operation of the lighting circuit shall be provided for each PEC.

The PEC shall work in conjunction with an external auxiliary load relay for handling the required lighting loads unless specified otherwise.

The PEC shall have a built-in lightning arrester. The encapsulated surge protector shall have a spark-over value of two kilovolts and shall interrupt up to 10 kiloamperes of follow-through current without affecting the operating characteristics. The PEC shall meet the following electrical requirements:

Supply voltage:	105 – 285 volts, 50/60 Hz., AC
Photo cell coil:	120 volts, AC
Inrush current:	120 amperes at 110 volts 60 amperes at 240 volts
Lamp Loads:	
Incandescent	1,000 watts
Mercury vapor	1800 volt-amperes
Fluorescent	1800 volt-amperes
HPS	1800 volt-amperes
Relay contacts:	Single pole, single throw, normally closed
Turn on:	1.0 ± 0.2 foot candles
Turn on maximum:	1.8 foot-candles
Life at rated load:	5,000 on-off operations minimum 130 amperes @ 120 volts AC
Operating levels:	65 amperes @ 120 volts AC

Turn off Average:	3.0 foot-candles
Control power:	0.65 watts maximum (120 volts AC)
	3.2 watts maximum (240 volts AC)

(2) Auxiliary Contactor:

Unless otherwise specified, an auxiliary contactor shall be used in conjunction with a PEC to control the required lighting loads. The contactor shall have contacts rated to switch the specified lighting loads and shall be normally open. The contactor shall be single-pole or double-pole as required. The contactor shall be installed as shown on the plans.

The contactor shall be of the mechanical armature type and shall consist of a 120-volt operating coil, a laminated core, a laminated armature, contacts, and terminals. The contacts shall be fine silver, silver-alloy, or other superior low contact resistance metal.

(3) Manual-Off-Photo Switch:

A manual-off-photo switch shall be installed, as shown on the Standard Drawing to manually activate the contactor to turn the lights on or off. The switch shall be the toggle-type having double-pole, double-throw contacts with the center position being the "off" position, and be rated at 10 amperes at 250 volts A.C. The switch shall be manually activated in the up position and shall be activated by the PEC in the down position.

736-2.02 Sign Lighting Materials:

(A) General:

Sign lighting fixtures and all necessary hardware shall conform to these specifications, and shall be UL approved. Each sign lighting fixture shall be designed for mounting at the top of the sign panels as shown on the plans on an overhead sign structure. The mounting and number of fixtures required per sign shall be as shown on the project plans. All sign lighting fixtures shall be supplied complete with lamps.

(B) High Pressure Sodium Fixtures:

High pressure sodium sign lighting fixtures shall be designed for mounting at the top of the sign panel on an overhead sign structure. The fixture shall be of an enclosed design and shall be watertight and corrosion resistant. Each fixture shall consist of a housing with upright shield, door, reflector, refractor, lamp, socket assembly, internal ballast, terminal block, quick connect harness and all necessary hardware. The fixture shall be UL listed and shall conform to the following:

(1) Housing:

The housing shall have a door designed to hold a refractor. Housings and doors shall be fabricated of die-cast aluminum. All external bolts, screws, hinges, hinge pins and door closure devices shall be stainless steel.

Each housing shall be drilled and tapped for 1-1/4 inch conduit at the center of the fixture nearest the sign panel.

Each housing shall be provided with holes as recommended by the manufacturer to permit condensed water to drain. Each hole shall be countersunk to a depth appropriate for the thickness of the housing.

The door shall be hinged to the housing on the side of the fixture away from the sign panel and shall be provided with two captive latch bolts or other closure devices. The door shall include an integral glare shield.

The juncture of the door and the housing shall be gasketed to provide a watertight and dust-tight joint. The gasket material shall be a minimum 3/8-inch seamless closed cell sponge EPDM meeting UL specification requirements for tensile strength and elongation after seven days aging at 113 °C.

(2) Reflector:

The reflector shall be one-piece hydroformed and shall be made from specularly finished aluminum protected with an electrochemically applied anodized finish. The reflector shall be designed so that water deposited on it due to condensation will drain away. The reflector shall be contoured to match the refractor design.

(3) Refractor:

The refractor shall be made from borosilicate heat resistant glass. The outer surface of the refractor shall be smooth and the inner surface shall contain the splitting and bending prisms. A single-piece weather resistant gasket shall seal the refractor to the housing. The refractor shall be so designed or shielded that no fixture luminance is visible when the fixture is approached directly from the rear and the viewing level is the bottom of the fixture. When a shield is used it shall be an integral part of the door casting.

(4) Lamp:

Each fixture shall be furnished with a 150-watt high pressure sodium lamp, ANSI code: S55SC-150, in accordance with the lamp table of Subsection 736-2.01(C)

(5) Lamp Socket:

Each lamp socket shall be a porcelain enclosed mogul type. The socket shell shall contain integral lamp grips to assure electrical contact under conditions of normal vibration. The center contact shall be spring-loaded. Shell and center contact shall be nickel plated brass. The socket shall be rated for 1,500 watts, 600 volts.

(6) Ballast:

The ballast for each HPS sign fixture shall be 100 percent copper wound and shall be designed for the characteristics and wattage of the lamp it is to operate, and it shall provide the proper starting voltage and operating waveforms, voltage and current.

Ballasts shall be of high power factor lag circuit design, capable of starting and operating one 150-watt high pressure sodium lamp within the limits specified by the lamp manufacturer.

Ballasts shall be 100 percent copper wound and have a Class H insulation system. Core laminations shall be M6 magnetic steel.

A ± 10 percent line voltage variation will not result in more than a ± 10 percent variation in wattage. Input wattage shall not exceed 188 watts. The power factor shall be over 90 percent throughout the life of the lamp.

The core-coil, starting aid and capacitor shall have a minimum ambient starting temperature of -40 degrees F and be capable of operating for a six month period during a short circuit failure, lamp open, or end of life cycle without any measurable deterioration to the ballast.

Ballasts shall have a design life of not less than 100,000 hours.

The input voltage for ballasts shall be as shown on the plans or as specified in the Special Provisions.

Each ballast shall consist of separate components, each of which shall be capable of being easily removed. Each component shall be provided with screw terminals, NEMA tab connectors or a single multi-circuit connector. All conductor terminals shall be identified as to the component terminal to which they connect.

Heat generating components shall be mounted so as to use the portion of the sign lighting fixture housing upon which they are mounted as a heat sink. Capacitors shall be located as far as practicable from heat-generating components or shall be thermally shielded to limit the case temperature to 75 °C.

Transformers and inductors shall be resin-impregnated for protection against moisture. Capacitors shall be metal cased and hermetically sealed.

(7) Terminal Block:

Each fixture shall be provided with a barrier type terminal block for terminating field connections. The terminal block shall be secured to the housing and shall be provided with protection from water due to condensation. Means shall be provided for both fusing and disconnecting the input circuit. Fuses shall be 12/32-inch diameter, 1-1/2 inches long ferrule type and shall be UL listed. Fuses for use with 120-volt input fixtures shall be rated at six amperes, 250 volts; fuses for use with 240-volt and 480-volt input fixtures shall be rated at three amperes, 600 volts. A quick connect wire harness shall be included for internal wiring.

(8) Performance:

When the fixture with its specified lamp is located so that the light center of the lamp is four feet in front of, one foot above and centered on a sign panel eight feet high and 16 feet wide, the ratio of the maximum to minimum illuminance level on the panel shall not exceed 4.65-to-one and the average to minimum illuminance ratio shall not exceed 2.75-to-one. In addition, the illuminance gradient shall not exceed two-to-one. The illuminance gradient is defined as the ratio of the minimum illuminance per one square foot of panel to that on any adjacent square foot of panel (square panel of the same size). The average maintained illumination level on the panel shall be 20 foot-candles.

(9) Uplight Shield:

The fixture shall be provided with an uplight shield that eliminates light above the horizontal plane. The shield shall be of the same manufacturer as the fixture, constructed of 0.060-inch aluminum sheet material and shall be mounted with a minimum of eight stainless steel screws. The shield shall be finished inside and outside with a baked polyester powder paint with a minimum 60 percent reflectance to match the luminaire. The shield shall be configured to provide zero light above the horizontal plane, as shown by independent test lab reports. The contractor shall furnish the Engineer with certified copies of the results of the independent test lab reports. The equivalent projected area shall be 1.4 square feet maximum. The shield shall flare at 45 degrees from the fixture housing to a point 1/4 inch below the lowest horizontal plane of the refractor.

736-2.03 Load Center Cabinets:

Load Center cabinets, including pole mounted cabinets shall have photoelectric controls and shall also include the concrete foundation, conduit stub-outs, meter socket, rigid metal conduit riser, cabinet housing, panel, breakers, contactor, selection switch, fuses, dry transformer, internal wiring and other incidentals in accordance with the project plans and these specifications.

The load center cabinet housings shall be of a NEMA 3 weather resistant construction. The steel cabinet housing and accessories shall be treated on the inside and outside with one coat of primer paint and painted with two coats of aluminum paint in accordance with Section 1002. Cabinets shall have continuous welded seams on all outside seams.

Circuit breakers shall be molded case, thermal magnetic, bolt-on or plug-in type and shall be U.L. listed.

Load center cabinets shall have a dead front panel to isolate all live electrical circuitry. The panel shall be fabricated from 14-gage sheet steel and shall be painted the same as the cabinet. The dead front panels shall be hinged on one side and securely fastened on the other with bolts. Switches, breakers and other components shall have openings to operate from the front panel.

736-3 Construction Requirements:

Field adjustments of the lamp sockets shall not be made for horizontally-mounted type luminaires. The lamp socket shall be adjusted at the factory to achieve the light distribution as specified on the plans and in the Special Provisions.

After the poles have been erected and plumbed, the vertical-mounted type luminaires shall be aimed as described on the instruction sheet and specified herein. The contractor shall provide and utilize a manufacturer-supplied aiming device to adjust the tilt angle of each luminaire. The device shall be adjusted to the numerical factors given for each luminaire in the tilt-angle column of the project plans. Operation of the aiming device shall be as described on the instruction sheet.

The contractor shall maintain full nighttime operation of the existing lighting system during the duration of the construction project.

736-4 Method of Measurement:

Luminaires will be measured as a unit for each luminaire furnished and installed.

Load center cabinets will be measured as a unit for each load center cabinet furnished and installed.

Sign lighting fixtures will be measured as a unit for each fixture furnished and installed.

736-5 Basis of Payment:

The accepted quantities of luminaires and load center cabinets, measured as provided above, will be paid for at the contract unit price each, for the types of luminaires and load center cabinets designated in the bidding schedule, complete in place, which price shall be full compensation for the work described and specified herein and on the plans.

The accepted quantities of sign lighting fixtures, measured as provided above, will be paid for at the contract unit price each, complete in place, which price shall be full compensation for the work described and specified herein and on the plans, including incidentals such as mounting hardware, electrical wiring and conduit on sign structure and to adjacent pull box, circuit breaker disconnect, and any other equipment necessary to complete the work.

SECTION 737 INCIDENTAL ELECTRICAL WORK:

737-1 Description:

The work under this section shall consist of maintaining existing traffic signals and lighting systems, furnishing and installing complete and functioning temporary traffic signal systems, and removing and salvaging or reinstalling electrical equipment; all in accordance with the project plans and the requirements of these specifications.

737-2 Materials:

737-2.01 Maintaining Existing Traffic Signals and Lighting Systems:

Replacement items necessary for maintaining existing Traffic Signal and Lighting Systems shall be of similar make and manufacture and meet the minimum material requirements of those items they are to replace.

737-2.02 Temporary Traffic Signals:

(A) General:

Department approved pole-line hardware shall be utilized in the installation of poles, messenger cable, pole anchors, etc.

(B) Wood Poles:

Wood poles shall be 35 feet in length, Class 3, unless otherwise specified, and meet the requirements of Section 731 of the Specifications. Holes for poles shall be dug at an angle with the vertical to allow for proper raking of the top of the pole. Poles shall be set six feet deep in the ground, be well tamped, and raked one foot out from the vertical position and in line with the pull of the cable.

The wood poles for temporary signals and their associated cables, wires, supports, etc. shall be located so as to provide clearance for all permanent construction.

(C) Messenger Cable:

The messenger cable used for aerial signals and anchoring shall be 3/8-inch minimum, seven-strand, high-strength grade, galvanized steel messenger cable securely attached to the poles and anchors in an approved manner.

(D) Department Furnished Material:

The Department will be responsible for any changes required in the control cabinet. The existing pedestrian units shall be used on the temporary traffic signals. The existing controller cabinet shall be used. All other equipment and materials necessary for the temporary signals shall be furnished by the contractor.

737-2.03 Removing and Salvaging or Reinstalling Electrical Equipment:

Replacement parts for salvaged or reinstalled electrical equipment shall meet the material requirements for like items as hereinbefore specified, as directed by the Engineer, or as designated in the Special Provisions.

737-3 Construction:

737-3.01 Maintaining Existing Traffic Signals and Lighting Systems:

All existing traffic signal and lighting systems or other designated electrical systems, shall be kept in effective operation for the benefit of the traveling public during the progress of the work, except when shutdown is permitted to allow for alterations or final removal of the systems. The work shall also include the relocation and/or modification of existing traffic signals and lighting systems as required during construction.

The traffic signal system shutdowns shall be limited to the normal working hours as directed by the Engineer. During periods of shutdown, flaggers shall be employed to manually direct traffic. At all other times, the traffic signal system shall remain operational.

All traffic signal heads not in use shall be covered with burlap and shall be unmistakably out of service when observed by an approaching driver. Plastic coverings shall not be allowed.

During construction, the maintenance, care and control of the existing traffic signal control cabinet will be the responsibility of the Department or the local agency. All other maintenance of the existing traffic signal system shall be accomplished by the contractor.

The contractor shall maintain full nighttime operation of the existing lighting system for the duration of the construction project. The contractor shall designate a person who will be available for emergency maintenance calls after normal working hours. The contractor shall furnish this person's name and telephone number to the Engineer. The contractor shall have labor and the necessary equipment available on a 24-hour per day basis for such emergency maintenance.

737-3.02 Temporary Traffic Signals:

Messenger cable shall have a maximum sag of five percent of the distance of spans. The lowest point of any back plate shall initially be 17 feet above the roadway to allow for settling of poles and anchors. Backplates shall be maintained so that the clearance between the lowest point of any backplate and the future finished roadway grade shall be not less than 16 feet. The contractor shall check each day to insure that the minimum clearance is maintained and shall take corrective measures if necessary.

Cable rings on 24-inch maximum spacing shall be used to secure the signal wires to the messenger cable. The wires shall also be taped to the cable if necessary to prevent excessive and unsightly slack in the line(s).

The continuous operation of traffic signals shall be in accordance with the requirements of Subsection 737-3.01.

The contractor shall maintain the electrical systems for the duration of the construction project. The contractor shall designate a person who will be available for emergency maintenance calls after normal working hours. The contractor shall furnish this person's name and telephone number to the Engineer. The contractor shall have labor and the necessary equipment available on a 24-hour per day basis for such emergency maintenance.

When required, the contractor shall remove and salvage all material associated with the temporary traffic signal. All salvaged material shall be the property of the Department and shall be dismantled and stockpiled as directed by the Engineer. Material broken or damaged by the contractor shall be replaced with new and like material at no additional cost to the Department. It shall be the responsibility of the contractor to remove and dispose of all traffic signal equipment and materials not salvaged.

Cavities resulting from the removal of pull boxes, foundations or other material shall be backfilled and compacted with material equivalent to or better than the surrounding material.

737-3.03 Removing and Salvaging or Reinstalling Electrical Equipment:

The contractor shall remove and salvage all existing traffic signal and lighting equipment as specified in the Special Provisions, project plans, or as directed by the Engineer. The work shall also include the removal and disposal of foundations. All equipment and materials to be salvaged shall be the property of the Department. Salvageable material shall be dismantled and stockpiled, prior to project completion, as directed by the Engineer or as shown on the plans.

All equipment damaged or destroyed by improper care or handling shall be replaced with new equipment. Unless otherwise specified, it shall be the responsibility of the contractor to remove and dispose of all discarded materials not salvaged. Holes resulting from removal of pull boxes, foundations, and other material shall be backfilled and compacted with material equivalent to the surrounding area or as designated by the Engineer.

When salvaged equipment is to be reinstalled, the contractor shall furnish and install all necessary materials, equipment, and hardware as required to complete the new installation. Reinstalled poles, pull boxes and cabinets shall be relocated as shown on the plans, with conduit and conductors installed, and all circuit connections complete and operational. Signal faces, mounting assemblies and backplates shall be cleaned and repainted when reinstalled. All traffic signal faces, either to be reinstalled or part of a modified system, shall be relamped. Luminaires to be reinstalled shall be cleaned and relamped.

Existing materials to be relocated and found to be unsatisfactory by the Engineer shall be replaced with new material and will be paid for in accordance with the requirements of Subsection 109.04.

737-4 Method of Measurement:

Maintaining existing traffic signals and lighting systems will be measured as a single, complete unit of work.

Temporary Traffic Signal will be measured as a single, complete unit of work.

Removing and salvaging or reinstalling electrical equipment will be measured as a single, complete unit of work.

737-5**Basis of Payment:**

The accepted quantities of maintaining existing traffic signals and lighting systems, measured as provided above, will be paid for at the contract lump sum price, which price shall be full compensation for the work, complete, as specified and described herein, and as shown on the project plans.

The accepted quantities of Temporary Traffic Signal, measured as provided above, will be paid for at the contract lump sum price, which price shall be full compensation for the work, complete in place, as specified and described herein, and as shown on the project plans.

The accepted quantities of removing and salvaging or reinstalling electrical equipment, measured as provided above, will be paid for at the contract lump sum price, which price shall be full compensation for the work, complete in place, as specified and described herein, and as shown on the project plans.